Vol 2

THE

NATURAL HISTORY

OF THE

MINERAL KINGDOM.

EDINBURGH:
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THE NATURAL HISTORY OF THE MINERAL KINGDOM,

RELATIVE TO

THE STRATA OF COAL, MINERAL VEINS, AND THE PREVAILING STRATA OF THE GLOBE.

IN TWO VOLUMES.

BY JOHN WILLIAMS, F.S.S.A.
MINERAL SURVEYOR.

THE SECOND EDITION.

WITH AN APPENDIX, CONTAINING A MORE EXTENDED VIEW OF MINERALOGY AND GEOLOGY.

ILLUSTRATED WITH ENGRAVINGS.

BY JAMES MILLAR,
M.D. F.S.A.S.
And Lecturer on Natural History and Chemistry, Edinburgh.

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VOLUME SECOND.

THE

MINERAL KINGDOM.

PART III. CONTINUED.

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OF OTHER INTERESTING SUBJECTS OF THE MINERAL KINGDOM, VIZ. OF VOLCANOES AND EARTHQUAKES.

THE natural history and phenomena of volcanoes are extremely mysterious and difficult to be explained, because we cannot descend into a volcano to examine circumstances. However, in a work of this nature, upon the Mineral Kingdom, it would be unpardonable to pass over volcanoes in silence, without communicating some of my thoughts upon this subject; and I the more willingly enter upon this task, as I am in hopes of being able to throw out some observations which may be of use, in future, to mitigate the calamities suffered by the miserable inhabitants of volcanic regions.

Volcanoes will, in many respects, for ever remain awfully mysterious; at the same time, there are several circumstances relating to them, which may be judged of by analogy.

It is more than probable, that the inflammable matter, which at first was the cause, and continues to be the fuel of volcanoes, is contained in veins which cut and intersect the bowels of the volcanic mountains and the adjacent plains; and I think it may be suggested as equally probable, that those veins are of the same species and description as mineral veins, in which useful metals are found: and if this be allowed, I imagine, that useful discoveries may be made for the future safety of the inhabitants of volcanic neighbourhoods; and, therefore, I will suggest a few hints for that purpose.

There are two kinds of mineral veins, which are known to trend in a pretty straight line to a considerable distance. Many of these veins have been traced for several miles. The one of these is the perpendicular mineral fissure, called by some miners a *rake vein*, and the other is the *flat* or *dilated vein*. Rake veins are found to cut the strata in a direction nearly south and north, and east and west. I say nearly, for the bearing of the veins is to the east of north and to the west of south; but the south and north veins are commonly found to contain the greatest quantities of metallic ores. The flat dilated veins do not cut the strata at all, but are found between two particular beds of stone; one of which is immediately above, and the other immediately below the vein; and the vein is contained in the space betwixt these two layers or beds of stone; of consequence, the bearing of the flat vein is the same as the bearing of the strata which, in European latitudes, is less or more to the east of north and west of south. Many of the rake veins are commonly very narrow or close near the superficies of the strata. I have often seen them so narrow for two or three hundred feet below the surface, that the sides of the veins would not open above three or four inches asunder in all that depth; and yet, nevertheless, they would gradually open further down, to the wideness, not only of several feet, but of several yards; and it is generally in these wide concavities of the veins that the greatest bodies of metallic ores are found; and very probably it is in such receptacles that the greatest quantities of volcanic fuel are lodged.

The flat veins found between the strata are not to be investigated upon the same principles as the rake veins; nevertheless, these also are frequently very straight or close near the superficies of the strata. The space between the two strata which constitute the upper and nether side, or roof and sole (as they may be called), of this vein, is seldom regular or equidistant. In some places they come close together, and continue so for a less or greater space; and in other places or parts of the same vein, they open asunder, and form enormous cavities, which frequently trend in a horizontal direction; and the direction or bearing of such cavities is generally north and south, or between that and the collateral points of north-east and south-west.

The east and west rake veins intersect those which trend from south to north, nearly at right angles; and they cut the strata in a line nearly right across the bearing, and parallel to the declivity or slope. The flat veins situated between the strata likewise open into cavities from west to east: That is, besides the cavities in the flat veins mentioned above, which run parallel to the bearing of the strata, there are also found in them cavities which run at right angles across the other, in a line nearly from west to east, which comes to be parallel to the line of declivity of the strata; and as that is the case, it is easy to conceive, that the one end of these last mentioned cavities points up toward the surface, and the other end points slanting downwards into the body of the earth, with a degree of slope exactly equal to the declivity of the strata in that particular place. From what has been said concerning the east and west cavities of the dilated veins, it will clearly appear, that the east end of each of these cavities gradually dips down under more and more cover, until at last it arrives under a prodigious weight and strength of the incumbent strata, even to many hundred fathoms perpendicular of solid rock. There are found some rake veins running in collateral lines between the two lines abovementioned; but as these are only inferior strings, branching off from the capital south and north and east and west veins, they only continue their course or line of bearing to a short distance from the veins from which they branch out, and then they come to nothing; that is, the sides of this string, which for a while cut the strata in an oblique or diagonal direction, come close together at a short distance from the capital vein, and at last end in a mere crack in the strata; and a little further forward the strata are found solid, without the least symptom of any vein in the line of bearing.

From this sketch of the history of mineral veins, it appears to me very evident, that the greatest quantities of volcanic fuel is lodged within the solid superficies of the earth, in veins and receptacles which have nearly a north and south bearing, from the mountain or other place where the volcanic fire first broke out; and that the volcanic fire, and consequent excavations, will advance below ground in the same direction. Now, if this is found to be true, we shall be enabled to lay down such cautions and rules, as will be of general utility for the safety of the inhabitants in the neighbourhood of volcanoes. I write only from my own observation, and real knowledge of the interior structure of the superficies of our globe; and from my knowledge of the structure, disposition, and bearing of the strata of rocks, of which the superficies of the globe in all parts of the world is composed, it appears to me, that the bearing of the strata in the island of Sicily, which suffers so much from volcanoes, should be nearly in a line from S. S. W. to N. N. E. and consequently, that the bearing of the veins which contain the volcanic fuel should trend nearly in the same line of direction; and I think, that Messina, and those parts of Calabria which suffer so much from earthquakes, are pretty much in this line.

If, upon examination of circumstances upon the spot, it is found, that the site of Messina, &c. is nearly upon this point of the compass from Mount Ætna, or any where between the cardinal point north and the collateral point north-east, and that the volcanic regions of Calabria are in the same line, that is, nearly N. N. E. from Ætna, it may be concluded, that my observations are founded in truth, and that there is no safe ground for founding a city, town, or harbour, any where near that line.

There are certain classes or arrangements of strata, of particular characters and qualities, which accompany one another in longitudinal districts upon the face of our globe. These arrangements of concomitant strata are found in patches of lesser and greater dimensions; but generally extending further in the line of bearing than in the line which crosses the strata. In some of these distinguishable classes of strata, seams of pit-coal are most frequently found, others produce the greatest number of lead and copper mines, &c. and it is highly probable, that there are certain arrangements of co-natural strata, in which the greatest quantities of volcanic fuel is lodged.

If it be judged, that the hints which I suggest upon this subject come near the truth, let the intelligent naturalist traverse the neighbourhood of Mount Ætna, and between that mountain and Messina, and let him examine the nature, colour, and quality of the several strata in that line, and likewise in the continuation of the same line into the volcanic regions of Calabria. I suppose that much of the surface of the ground near Ætna is covered with lava, ashes, and other rubbish, where the strata cannot be seen; however, he will see them in several places in that line, and especially upon the shores of Sicily and Calabria. When he has satisfied himself with respect to the quality and characters of the prevailing strata in that line, then let him examine the strata, either inland or along the shores of the Mediterranean Sea, wherever he can best see them in a line from west to east, right across the bearing of the strata, which we have supposed to be about N. N. E. and S. S. W. and when he meets with an arrangement of strata, or rocks of a quite different quality and colour, &c. from those found in the volcanic line, he may conclude, that he is in a place of safety for the foundation of a city or harbour, &c. especially if he be far enough east or west from the line of the supposed range of the volcanic strata. The principal crater on the summit of Mount Ætna may be supposed to be the centre of the volcanic ground, though that is a little uncertain, as we cannot positively determine whether the veins and excavations of that mountain at great depths have advanced farthest towards the east or west: Perhaps, however, we can fix upon no better point than the great crater, from whence to draw the line towards Messina and Calabria. If the superficies of the srata about the foot of the mountain could be seen, the naturalist might guess pretty nearly what is the breadth of the volcanic ground in the island of Sicily; but as I suppose he cannot see the strata about the mountain, he must be the more careful to investigate circumstances upon the sea shores, the banks of rivers, and other places near Messina and in Calabria, where the superficies of the strata is to be seen; and when the best judges of these matters have acquired sufficient degrees of knowledge of the distinguishable characteristic qualities of the strata of the volcanic region, to be enabled to form a safe and prudent plan for the site of sea-ports and cities, far enough from dangerous ground, then let Messina, and all the regions in Sicily and Calabria which have suffered from earthquakes and volcanic eruptions, be abandoned by the generality of the people, and adapted to husbandry only, which requires but few people, who can easily remove for a while in time of danger to places of safety; that is, to fly off the line of the volcanic ground to places which suffer least from these calamities. It is presumptuous, and in a high degree dangerous, to think of living in Messina, or any other of the towns or harbours in Sicily or Calabria, which have recently, or at any former period, suffered by earthquakes and eruptions; because the same places are in continual danger of suffering the same over and over again; and every succeeding shock should be worse or more dangerous than the former, because the rocky crust which lies above the volcanic excavations, and under such town, harbour, or other place, is greatly weakened by being shaken, rent, and shattered with former shocks; and there are only two chances in nature that can ever make those places safe for the habitation of man. The one of these chances rests upon the supposition, that the whole magazine of volcanic fuel in that region may be entirely exhausted, of which we can say nothing, as we cannot survey those magazines to enable us to judge of their extent and duration. The other chance is, that an earthquake or volcanic eruption should open such a breach in the bed of the sea, as to make room for the ocean to rush down in such a vast body as suddenly to fill up the excavated receptacles of the volcano, which must soon extinguish it altogether: but both these chances are too distant and uncertain ever to be trusted. It must happen, that several repeated volcanic concussions dry up many springs and rivulets, by which a great quantity of water is let down into the excavations of the volcano; but such comparatively small quantities of water have a direct tendency to aggravate the evil, and to make the volcano ten times more dreadful and mischievous, as every drop of that water is evaporated and reduced to highly rarified steam by the prodigious heat of the volcano. The experience of the steam engine enables us to form some idea of the prodigious force of steam, when it is greatly heated and confined.

When a copious stream of the atmosphere gets access into a volcano, and by its density and weight rushes into the remote excavations, and gets under or behind extensive clouds of steam, the consequences must then be dreadful. The expansion of the steam, before the external air is so copiously admitted, fills all the volcanic spaces; but the coolness of the air in part condenses the steam, which makes room for still greater quantities of air to rush in; but when the steam is again fully expanded, and the admitted air highly rarified by the excessive heat of the volcano, the united force of both is sufficient to convulse the whole globe, and to rend asunder the strongest bars of the earth, if it find not a thin enough crust of rock through which to burst a passage. What are the explosions of gun-powder, and any force of steam which we can bring to act, but trifling experiments, and childrens play, in comparison of these mighty operations and effects! It is only in the volcano that they act like the great works of nature. When sufficient quantities of these powerful agents get behind melted and unmelted matter within the receptacles of the volcano, and are fully rarified, when the explosion happens, if the vent be wide enough, it will drive out every thing before it through the mouth of the crater: But if the passage be too straight, or be obstructed by falls of the rock within, by congealed lava or otherwise, in that case it must and will burst up the rock, and make a new vent or passage.

From all these considerations, when viewed jointly and separately, there appears no place of permanent safety within the line and limits of the volcanic fuel, which I wish to be able to point out, and which I hope will in time be found and understood; and as there is no permanent safety, neither is there any possibility of knowing when or where the earth may be convulsed and rent again and again within the old volcanic limits; nor is it easy to judge how far the subterranean fires may advance in the line of bearing, which we have supposed to be in Sicily and Calabria about N. N. E. and S. S. W.

These hints, which are well intended, are founded either in experience or upon solid principles; and, therefore, they deserve to be seriously and thoroughly investigated; and, perhaps, being thrown out by a plain practical man, may be the means of suggesting to naturalists such further discoveries and improvements as will conduce to the safety of the inhabitants of volcanic countries. For if proper rules can be laid down for the safety of one country that is disturbed by volcanoes, it is to be supposed, that the same rules will hold good every where, making proper allowances for the different bearings of the strata in different latitudes. Now, the bearing of the strata at the equator must be true south and north; and as we recede from the equatorial regions towards the northern tropic, the bearing of the strata inclines gradually towards the east of north; and as we advance from the tropics towards the north-pole, the bearing of the strata inclines gradually more and more, until at last it comes to be north-east. The strata trend gradually towards the east to the south of the equator in like manner as to the north.

It may be proper to observe here, that, in some particular circumstances, the strata in a small spot or district may, and do, vary and deviate from the true general line of bearing; as, for instance, when the strata lie in the horizontal position, they are in that case found to wave up and down, and to dip this way and that; and while they continue thus to wave up and down, they acquire many different bearings and slopes, frequently towards all points of the compass. But this accident is not of any great continuance: It only happens upon a small scale, and in a small district, but does not in general affect or alter the true line of bearing.

By these inquiries and investigations, naturalists may become the ministers of health and safety to numbers of mankind. And how can they attain greater honour or happiness! And what signifies the idle selfish pomp of learning and knowledge, if it be not exerted for the good of the world?

I will add, in this place, a strong argument to enforce the examination of this subject, which is this: We find, in experience, that the Almighty seldom or never sends a great calamity to scourge the children of men, but he also, at the same time, points out, or puts in our power, an antidote or means which wisdom and caution may lay hold of, and use to mitigate the severity or extreme rigour of such calamity.

A great many examples of this might be given to show, that the all-wise Governor of the world, in the midst of judgment, remembers mercy, and puts the means of deliverance or of mitigation in the power of prudence and exertion; but I will only point at one instance, viz. the. small-pox, as one of the severest scourges of the human race.

In some countries it sweeps away whole tribes at once, and in almost all places, prodigious numbers are destroyed by this loathsome malady; but now, and even long ago, Providence pointed out inoculation, as not only a happy means of mitigating the rigorous and destructive severity of this dreadful malady, but in a great measure as a perfect antidote; for many physicians in Britain have inoculated thousands without hardly losing one, and almost without leaving a single mark of their patient's ever having had the small-pox; whereas the few who escape life, when smitten in the natural way, without being inoculated, find blindness and deformity are but too commonly entailed upon them as long as they live.

It was a long time before inoculation prevailed among us in all parts of Britain. It is to be wished, that now, when philosophy and science have arrived at such degrees of perfection in Europe, and that earthquakes and volcanic eruptions have become so common, and so destructive in many parts of the world, that proper means to mitigate and to shun the dismal effects of this calamitous scourge could be found out, and sure rules formed for the future safety of the inhabitants of those countries. I think this attainment not only possible, but also practicable; and this persuasion is not only founded upon a fervent desire that the above hints may answer the design for which they are written, but is also founded upon the equal, wise, and benevolent providence of God, who never sends a scourge, and permits a severe evil to visit mankind, but he also sends the means of escaping, or at least of mitigating that evil.

It is said, that necessity is the mother of invention; and I hope that the great and pressing necessity of this case will prompt those who are chiefly concerned to attempt the remedy, or at least the mitigation of this great evil; and there appears to me no sure remedy in nature, or, in other words, no sure means of mitigating this evil effectually, but for the bulk of the inhabitants of such countries to shun the line of volcanic ground, and to leave those dangerous situations, where so many of their brethren have perished in a moment, to be occupied by farmers only, who should live in tents, or in other slight habitations, which could not crush them by their fall, and which would be easily reared up again when thrown down by the concussions of earthquakes; and these farmers should be instructed which way to fly from danger to safer ground; and, moreover, they should be well instructed to understand and observe the signs and symptoms of approaching danger, that they may always have it in their power to provide for their safety by flight. I have no manner of doubt but there are external signs and appearances, and interior symptoms and warnings of approaching danger, which will be almost infallible when well understood, and well attended to. It has been observed, in many parts of the world, that the atmosphere is uncommonly agitated before any great earthquake. And it is said, that rumbling noises are heard under ground in volcanoes for some days before a great earthquake and eruption. Perhaps part of the cause of these subterraneous noises may be occasioned by copious streams of air and steam rushing out, when violently heated, through passages which are yet pretty clear and open; but that, during this time, streams of lava are propelled forward from remote parts or excavations of the volcano; but when this mighty stream of lava accumulates in a narrow mine or passage, then the catastrophe is near. The mighty gusts of volcanic respiration are at an end; but there is a quantity of air and steam behind the lava, which is increasing rapidly by the continual supply of water from a thousand vents, which is suddenly converted to steam; and when this steam is sufficiently heated, then an earthquake ensues, and the lava is either propelled to the surface by some of the old apertures, or new breaches are made where the rock is weak. Now, if we allow of this supposed violent respiration of the volcano for a few days before the earthquakes and eruptions, it will sufficiently account for the uncommon agitation of the atmosphere.

It is well known that springs and rivers are dried up by volcanoes, and all the rain and snow which fall upon volcanic ground, must find its way into the subterraneous excavations, excepting what is immediately evaporated upon the surface. Now, every drop of the water which rushes down through the natural and accidental fissures of such extensive rocks as cover, and are situated upon both sides of some ancient volcanoes, is converted into steam by the heat of the volcano; and such a quantity of water converted into steam, will soon fill all the excavations of the volcano like a thick cloud; and while this vapour is fed by continual and copious supplies from the feeders of water, and the extraordinary heat, the steam will so effectually fill all the receptacles of volcanoes as to exclude and prevent the admission of the external air into any of those receptacles.

I must not be understood to mean, that the external air is absolutely excluded from every part of the volcano. The fire could not exist without a communication of less or more of the external air; and the extreme degree of cold which those who visit volcanoes have found in some narrow caves and passages in the sides of volcanic mountains, is a clear proof of the air rushing violently through those fissures to fan and feed the fires below; but what I mean is this, that the great heat, with a thick and strong cloud of steam, will fill all the great excavations of the volcano, and effectually exclude the external air from entering through the crater; nor can it possibly get admission into those receptacles through the crater and main passage, while the heat and steam continue in full force *.

These hints are not merely conjectural. They are founded upon observation and analogy, in comparing great things with small, which is the surest way of coming at the truth. Steam from boiling water raised by great heat, and closely confined, is far stronger and more powerful than the weight of the atmosphere.

There is an inflammable vapour which often collects in remote mines, and other parts of subterraneous works, which are scarce of air; that is, where there is not a sufficient current of air to carry off this vapour; which being touched with a lighted candle, instantly takes fire, and goes off with an explosion like gun-powder, and with a force perhaps superior to it.

Now, here is another powerful agent found below ground, which, for any thing we know to the contrary, may be joined with other volcanic forces; and when such a small quantity of this vapour as

* The cold air must be excluded from volcanoes; otherwise steam or vapour would immediately be condensed and converted to the state of water, when it is deprived of its elastic force. Steam, it may be added, is invisible. The Author's views, with regard to the vapour of water and its effects, are not very correct.—EDITOR.

is contained within the space of a few cubical feet; or a small quantity of gun-powder, when properly confined, is capable of doing such mischief, and of proving so powerful, what may we not suppose the united force of the volcanic powers capable of doing, when they are in such immense quantities, and excited by such prodigious fires in the extensive caverns of volcanoes? But here all computation and even conjecture fail. We are not capable of forming a proper judgment of these stupendous and astonishing secret operations of nature. All we can do in such cases, is to have recourse to the effects to enable us to judge of the cause.

There is yet another very powerful agent in nature, which is pretty well known, though not so well understood; I mean electricity, and electricity is the action of fire. If we attentively examine this matter, we shall soon discover that fire is the most active, and I believe I may venture to say, the most powerful agent in nature.

That the atmosphere is plentifully mixed with latent elementary fire, is evident from its being procured several ways by attrition, as in artificial electricity, the friction of dry axles, the peg and board, &c. Now, when a copious stream of the atmosphere enters the mouth of the crater of a volcano, the heat of this prodigious furnace will cause the watery parts of the air to fly back; but the latent fire will rush forward to join its native element in the excavations of the volcano, and a vast increase of the elementary fire from the atmosphere will soon bring matters to a height, and produce dreadful earthquakes and eruptions.

Fire in one state, condition, or modification, or other, seems to be the most powerful and universally active principle and agent in nature. I do not know but it is the only active principle, and natural cause of force and motion in the universe. It is fire that thunders in the clouds, roars in the winds, and tears up the superficies of the earth in hurricanes; and undoubtedly it is fire that rends the rocks asunder, and shakes the foundations of the solid globe in earthquakes.

And it is the different mixtures, modifications, and motions of this element that produce all the mild, beneficial, and salutary operations of nature. It is fire that sustains the life, and promotes the growth of plants and animals; it moves gently in our mild salubrious fluids, and effervesces more fiercely in many hot and pungent liquids. In short, fire seems to be the only active principle in every fluid, and in every moving body; we can set no bounds to the power of this mighty agent.

I could make but little by further attempts to explain and illustrate the inexplicable operations of volcanoes; and as I think that I have now suggested sufficient hints to throw such light upon this naturally dark and difficult subject as may be of use to real philosophers, I will say no more upon this topic at present.

These reflections authorise us to conclude, that dreadful earthquakes and eruptions will frequently happen somewhere in the line of old volcanoes; and it is impossible to know when or where they will be most violent and destructive in that line.

What I mean by the line of volcanic ground has been pretty fully explained above, where it was observed, that the several species of mineral veins, which are found by experience to contain the greatest quantities of mineral matter, run in a line parallel to the bearing of the strata. This point being considered as an established fact, it will follow of consequence, that whether the volcanic fuel be chiefly contained in veins or in strata, in rake veins, or in flat dilated veins, which are situated between the strata, it will run in the same longitudinal line of bearing. I have some reasons for being persuaded, that the inflammable matter, which is the fuel of volcanic fires, is not contained in strata properly so called; though it may, and I am persuaded that it frequently is contained in the flat veins situated between the strata. One reason for my rejecting regular strata of volcanic fuel is this: It is well known, that in the structure of the stratified parts of the superficies of our globe, the one side, or the one edge of the several strata come quite up to the superficies of the solid part of the globe, though earth, clay, gravel, sand, &c. be frequently found of various depths lying above the superficies of the solid strata.

In this view of the subject, it appears that the one side or edge of every stratum comes up to the superficies of the solids; and, therefore, if the volcanic fuel were contained in regular strata, it would follow, that when a volcano was once kindled, it would burn forward in a line quite up to the surface of the ground; but as the volcano by this means would have regular breathing places, as we may call it, by communicating with the surface every where as it advanced in the line of bearing, few or none of the dreadful accidents attending volcanoes, such as earthquakes and eruptions, would happen. This we know by experience, as far as analogy will reach.

Seams of pit-coal are regular strata. They are sometimes set on fire by accident, and burn below ground for several miles. Now, this conflagration not only burns quite up to the surface of the solid strata, but it also burns such earth, clay, &c. as lie immediately above the solids in the line of bearing, and the several substances which come in contact with the fire at or near the surface, in the line of the crop or basset of the coal, are frequently vitrified, and run together in vast masses of slags resembling lava; but neither earthquakes nor eruptions ever happen from these subterraneous conflagrations, no doubt for the reason I gave above, viz. because this subterraneous burning communicates with the surface all along the line of the basset of the coal as it advances; and, therefore, the water which is evaporated, and the rarified air, find an easy passage to the surface. This is a pretty good example to enable us to judge of these matters by analogy *.

It has been observed, that mineral veins are frequently checked at the surface, the two sides of the vein being squeezed close together above; but besides this cause of preventing the respiration of volcanic fires, strata of different qualities may be spread over the bassets, vertex, or tops of the mineral veins in the valleys, which do not reach up to the site of the first craters upon the mountains. Strata of pit-coal, and their concomitants, are found in valleys, which do not ascend the high mountains of the coal countries. Veins of volcanic fuel basset out in the summits of high mountains, where they are first ignited; but when they burn down towards the bases of the mountains, these veins may be covered by other horizontal strata, containing no such veins or fuel.

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* The analogy here stated by the Author will not, perhaps, be considered by many as very apposite. The nature of the combustion of coal, and its causes, are often well known; but the nature of volcanic combustion, and the causes of the remarkable phenomena which accompany it, are involved in the deepest obscurity. The first is a case of simple combustion; the latter probably depends on the heat evolved during the decomposition of immense masses of matter.—EDITOR.

Mineral veins, whether vertical or horizontal, are exceedingly unequal in their capacities in different places of the same vein, frequently forming spacious concavities, and again contracting at a small distance into narrower bounds. Now, it is reasonable to suppose, that the capacious receptacles of these veins contain the volcanic fuel; and that, when the combustible matter is consumed out of these cavernous receptacles, they will be greatly enlarged by the vitrification and decomposition of vast quantities of such incombustible matter as come in contact with the prodigious fires and heat of the volcano; and it is as reasonable to suppose, that it is in these enormous caverns of fire that the causes of earthquakes and eruptions are generated. We cannot tell how deep or how far below ground these excavations may reach; but we know, that they can have no communication with the external air, but by the craters, or other apertures which the several earthquakes have made; and, therefore, no respiration or perspiration of the steam and rarified air can possibly happen here, as in the conflagration of a stratum of coal. It must either issue at the common apertures, or force a new passage elsewhere; and fatal experience makes it but too evident, that it frequently does make a new passage in great and destructive earthquakes.

Although the mineral veins, supposed to contain volcanic fuel, are very unequal in the capacity or dimensions of the concavities, they are nevertheless pretty regular in the line of bearing. I hinted before, that several veins run parallel to one another in mineral ground, and no doubt this will happen in volcanic ground. In some mining fields we meet with short veins, which cut right across between two capital parallel veins, and unite them together without crossing them. These short cross veins are frequently well replenished with mineral ores; and so they may with inflammable matter in volcanic countries; and if so, then the fire will easily communicate from one parallel vein to another. I hinted before, that many of the strongest and most productive mineral veins are piped; that is, are formed into long and high concavities, which run parallel to one another, and frequently point downwards in a slanting direction into the body of the earth.

These pipes resemble a number of long vaults, or arched cells, arranged parallel to one another, only not so regular. It is impossible for us to know how deep the veins and these pipes in them strike down into the body of the earth, whether the veins dip down precipitately, or with an easy gentle slope; and, therefore, it is impossible for us to know how deep the volcanic fire may penetrate; but this one thing, however, we may assure ourselves of, viz. that the deeper and more extensive the subterraneous excavations are, the more dangerous the volcano, and the more mischievous and extensive its effects; and the reason is obvious, viz. because the deeper and more extensive the excavations are, the more room there is for the reception of steam, air, &c. which, with the agency of volcanic fires, I have shown to be the efficient cause of earthquakes and eruptions.

It cannot be denied, that the excavations of old volcanoes are amazingly extensive. The immense quantities of lava and other matter ejected from them, proves this to a demonstration; and, therefore, it may be a query with some, how it happens, that the ground above these extensive excavations does not give way and fall in, not only around or near the original crater, but even every where in the course or line of the progress of the subterraneous fires, and produce numberless gulfs and chasms, both dangerous and frightful to behold? I answer, if the volcanic fuel were generally contained in regular strata, the earth would so fall in, because the combustible strata being consumed, the superincumbent strata would infallibly fall down when undermined to a vast breadth and length; and this must happen in the whole length of the volcanic excavations, and as far in breadth as they are undermined: But this not being the case, is another strong proof, that the fuel is lodged in mineral veins, which not only strike down deep into the earth, but are also frequently of a piped form, as we hinted before, which pipes sometimes stand nearly perpendicular, or with a considerable slope; and, therefore, every part of the intervening rock which separates the pipes from one another, is a strong pillar fixed upon its own base. It is known too by observation and experience, that the concavities of mineral veins more frequently expand or open out deep down than near the superficies of the strata. Many of the cavernous excavations of volcanoes are therefore, according to this piped form of the veins, exceedingly capacious at great depths; assuming an arched figure in many places, with a thick and strong crust of rock above the arched excavations, which does not contain any combustible matter.

The natural history of the solid superficies of the globe is a subject of difficult investigation; and there are but few, even of our philosophers and naturalists, who are well acquainted with its structure, which makes it the more necessary for me to be minute and circumstantial in explaining some particulars. In the practice of mining, we sometimes meet with what may be called *accumulated* or *concentrated* veins; that is, a number of veins or mineral fissures, containing rich ores, the one end of which converges and meets in a common center, and the other end of each of them diverges and spreads out from this center to some distance, though generally not very far. It frequently happens, that a vast body of ore is found in the center of this accumulated vein; and when the ore is dug out, a most tremendous gulf is opened below ground, which is sometimes of an irregularly arched or conical figure.

Now, it is fair and reasonable to suppose, that there may be vast accumulated veins of fuel in some volcanic mountains, perhaps of much greater extent and dimensions than we can easily conceive; however, the excavations of these, though vast and extensive, are nevertheless of an arched or conic form; and, therefore, the superficies is supported, and does not fall in. These subterraneous excavations may be compared to some immense Gothic temples, which, though of vast dimensions, the roof lofty, and composed of massy and ponderous materials, yet the fabric is firm and durable, because it is supported by walls, buttresses, and pillars, proportioned to the immense weight of the superstructure.

When the result of these inquiries is fairly examined, we shall be authorised to infer, that whether we suppose the combustible matter, which is the fuel of volcanoes, to be contained in mineral veins, or in regular strata, it is exhaustible. The progressive advances of some volcanoes, in a line from the first funnel or crater, is a proof that the fuel is exhaustible; and, moreover, some few volcanoes have been extinguished. We may also assert of volcanic fuel, that it is not only limited in quantity, and exhaustible, but that it is lodged in very widely different quantities in different places, like all other mineral matter. This observation is sufficiently proved by the different magnitude and extent of different volcanoes, which is the very best proof the subject is capable of, there being no possibility of surveying these treasures of fire.

It is fair and reasonable to suppose, that the volcanic fuel treasured up in Mount Ætna, and in the line of progress of that ancient volcano, has been many thousand times as much as some diminutive volcanoes, which can only be said to exist in a comparatively harmless state, without being of sufficient magnitude or force to do much harm. All mineral substances whatever, whether useful or curious, are found in very different quantities, in all the different places we dig for them, or see them basset out, where the superficies of the strata is laid bare by streams of water, or otherwise; and we are confident to assert, that there is the same variety or difference of quantity of volcanic fuel as of other mineral matter. These disquisitions are not the fruit of ingenuity and conjecture: Observation and experience assure us, that it is difficult to set bounds to great and little when applied to the concavities or capacities of mineral veins. We have seen some very small and diminutive, and we have seen others exceedingly large and capacious; and there is no room to doubt, that there are others at great depths in the bowels of volcanic mountains, which are prodigiously larger and more capacious than any that we see or penetrate in our diminutive operations and researches.

I suppose that new volcanoes must occasion but weak and harmless earthquakes, because there is not as yet extensive excavations made for the reception of copious vapours; however, in process of time, the continual consumption of volcanic fuel will soon make room enough to contain a sufficiency to push out streams of lava, or, by quick explosions, to throw quantities of rubbish high up into the air.

The inflammable vapour in coal mines frequently does this last in miniature. The increase and dilatation of a great cloud of steam, lodged behind a quantity of liquid fire or melted matter, will forcibly propel and thrust it out through the mouth of the crater. There is no room to suspect the propelling force of steam and rarified air in any direction whatever, it being the action of fire; and the more it is confined, the more powerfully it will act. If once it collect in force behind any quantity of lava, or other matter, it will violently push it out at the old, or burst a new passage. We are enabled to conceive a tolerable idea of the prodigious extent and capacity of the excavations of old volcanoes from the quantities of matter ejected from them.

Where we see countries overspread with lava for many miles in extent, and to a vast depth, and know that, besides the lava, immense quantities of pumice, ashes, and other rubbish, have been thrown out in different ages, we must conclude, that volcanic excavations are large and extensive, in proportion to the quantities of matter thrown out; and, moreover, when the original site of volcanoes is near the sea, perhaps we cannot guess at one half of the matter ejected, because immense quantities of it have been thrown into the sea, where it lies buried in the waters. We see enough, however, to assure us, that the excavations below are of immense extent; and I have no doubt that this is the cause of the earthquakes of old volcanoes being so extensive, and so disastrous in their effects, even at a great distance from the original site and crater. I dwell the longer upon these abstruse disquisitions, with the intention of impressing upon the mind an apprehension of the great danger of inhabiting volcanic ground, and especially every where in the line of an old volcano. The dreadful catastrophes which have so frequently happened in Sicily, Calabria, Peru, Jamaica, and many other parts of the world, are but too sure proofs of this danger; but there is, in many instances, a sort of infatuation in mankind. We are apt to overlook and forget our danger when the cause of it lies out of sight. I have, in these disquisitions, endeavoured to explain, and expose the causes of danger; and as far as my knowledge reaches, I have endeavoured to make the danger visible to the mental eye, to the end that those concerned may flee from it, at least, with their cities, sea-ports, and manufactories, and leave volcanic ground for the purposes of husbandry only.

I might now proceed in my inquiries, and attempt to investigate the original cause of volcanoes; but as the subject is both difficult and mysterious, and appears to me merely curious, I will not spend much time in disquisitions that can be of little utility. It is well known, that there are various quantities of iron and other pyrites in all countries; and these pyrites, which are sometimes pure and unmixed, and sometimes blended with other fossil substances, are frequently found between the sides, and in the cavities of mineral veins, in different proportions; or are imbedded in masses and plates, &c. of various thickness in the stratum of coal, and in many of the stony and argillaceous strata which accompany coal; and moreover, iron pyrites is often combined with, but concealed in invisible particles, throughout the whole stratum and mass of the coal, in such quantities as frequently to raise a fermentation, when such coal is heaped together in places accessible to the common air. This fermentation first raises heat, which is by degrees increased, until at last the heaps of coal are ignited. Several large parcels of coal in Scotland have been in a conflagration, and actually consumed, by this process; as, for instance, at Ayr, and at Brora in Sutherland. We have seen parcels of pyrites fermenting alone to the degree of ignition, when they have been thrown aside above ground; however, I will not assert, that such parcels were perfectly free from particles of coal adhering to some of the masses of pyrites.

Whether the fermentation of pyrites alone, or of sulphur and iron, or any other metallic substance, be adapted by nature for kindling and feeding the fire of volcanoes, or whether it be not necessary that there should be some bituminous or oily matter to increase and feed the flame, I will not pretend to determine. Perhaps other inflammable substances are also necessary at first to kindle and feed the flame; and such are frequently mixed in lesser or greater quantities with various strata, and are lodged in mineral veins. Petroleum is widely diffused through the mineral kingdom; and it is so plentifully combined or mixed with the substance of many species of stones and other fossils, as to cause them to flame strongly in the fire, though not to consume; and in many parts of the world, the petroleum is in such abundance as to issue out of the ground in great quantities.

There is a species of remarkably pure and fine coal, of a rich and fat quality, deposited in the cavities of mineral veins, which I have seen in several parts of the Highlands of Scotland. The greatest quantity of this coal is to be seen at Castleleod in Ross-shire, where some of the veins have been opened and tried. The nature and situation of this species of coal are extraordinary, and quite out of the course of common experience; for it is found in the cavities of rake-veins, or perpendicular mineral fissures; whereas other fossil coal is always found in regular strata.

Now, this brief sketch may suggest to us, at least a probability, that besides the immense stores of pyrites which are supposed to be lodged at first in the bowels of volcanic mountains, there may also be lesser or greater quantities of petroleum, or of some other combustible matter, either mixed and blended with the pyrites in the same veins, or deposited so near to one another, as that the combustibles would at first be readily ignited by the fermentation of the pyrites; and they may afterwards continue to the end reciprocally to inflame and consume one another. As I have seen different quantities of fossil coal in the cavities of mineral veins in several parts of the Highlands of Scotland, it cannot be called a stretch of vague conjecture to suppose, that the same, or some other inflammable substance, may be deposited in volcanic mountains, though the fact cannot be ascertained; because the superficial parts of volcanic fuel are there consumed away long ago. We may form several conjectures how a volcano is at first ignited; as, by elementary fire, or great and uncommon flashes of lightning kindling some easily inflammable substance, or of such flashes of elementary fire kindling dry and parched vegetables, and the conflagrations of these vegetables communicating fire to the superficies of a vein of some combustible fossil substance. With respect to this last conjecture, it may be observed, that the principal crater of many of the ancient volcanoes is situated higher up on the mountain than any vegetation is ever found; and as to the first, the inflammable fossils, especially such of them as partake of the nature of coal, are not so readily inflammable as to be ignited by a sudden transient flash of elementary fire; and, therefore, the most probable conjecture in my opinion is this, viz. That volcanoes are at first ignited by pyrites at the surface.

Moderate humidity, and the contact or action of the external air have a great tendency to excite and increase the fermentation of pyrites; and it is observable, that the summits of most volcanic mountains are covered with snow the greatest part of the year, and we cannot imagine a situation where the fermentation of those substances would be more powerfully excited than beneath the snow; and in lower situations, which are not often covered with snow, we may suppose, that the minerals have been sufficiently moistened by long and heavy rains, or by a copious spray from the sea. But after all that I have said, or perhaps that can be said upon this mysterious subject, I may not exactly hit the mark. I do not pretend positively to assert any thing. All that I can do is, to point out several observations and facts, and leave the reader to form a judgment of them for himself. My own opinion of the origin or ignition of volcanoes is this: I observed above, that accumulated mineral veins are found in some mining countries, where a number of nearly perpendicular fissures meet and join in one common center, from which they spread out like radii to different distances from the central conjunction. Now I suppose, that there was one of these accumulated veins in each volcanic mountain; that the central part of the vein came up to the day at or near the summit of the mountain; that this vein contained pyrites, perhaps mixed with other inflammable combustible fossils; that the rains, and especially the snows, excited these inflammable mineral substances to such a degree of fermentation as to be at last ignited; and that, when once kindled, the fire would first prey upon the shaft or central column of the vein, which of course would form in time a vast perpendicular cavity, resembling the inside of a glass-house. Some of these accumulated veins of vast magnitude have been seen and explored in the practice of mining, and in cavernous mountains.

Now, as these concentrating veins are seen of different degrees of magnitude, it is agreeable to analogy and experience to suppose, that at great depths in the bowels of volcanic mountains, such veins have opened and expanded to degrees of wideness and capacity far exceeding any thing we have seen, and that they have been replenished with volcanic fuel. Upon this hypothesis, the first great excavation of a volcano should be much in the form of an irregular conical shaft, the crater being the mouth of the shaft, the extent of which is sometimes seen; but we can say nothing about the depth, dimensions, and capacity of those volcanic shafts which are out of our sight. But whatever may be their extent and capacity in the bowels of the mountains, this account of them presents to us the idea of a strong arched figure, like a glass-house, every part of which is well supported upon its own basis; and I am fully convinced, that this subterraneous form is the real cause or reason why those mountains do not fall down into the immense gulphs and excavations below. In the progress of volcanic conflagrations, some of the diverging rays or branches of the accumulated vein will communicate with veins of another description, which trend in a line parallel to the bearing of the strata; and as the volcanic fuel is the prevailing mineral substance or substances of that district, the parallel veins will likewise be replenished with volcanic fuel; and, therefore, in process of time, the volcanic fire will prey upon those veins, and advance in a horizontal direction; and when the excavations are become extensive and capacious, they also become dangerous and destructive, as at Messina, Calabria, Jamaica, &c.

Some noted volcanoes, such as those of Iceland, not only emit great quantities of steam, but throw out also great quantities of hot water high up into the air several times every day. We presume, that the natural cause of this phenomenon is a subterranean river, and a thin partition wall of rock interposed between the river and the volcano. This partition wall must be a species of fire-stone, perhaps basalts, some of the varieties of which is the best fire-stone that we know of; that is, it stands the heat of a furnace, or any other strong heat, better than any other of our hard stone. We are told that basaltine rocks abound in Iceland, and especially in the neighbourhood of the volcanoes, and that the apertures, through which the hot water is ejected there, are in rocks of basalts. This partition wall being heated to different degrees, may produce the different phenomena and ejections of the water and steam; and, moreover, in some of them, there may be a passage or gap below, in what may be called the banks of the river, over which the water may run sometimes, and fall down into the volcano, which may be the cause of its raging more furiously, and of ejecting the water, &c. with more than ordinary force and violence.

I will now proceed with some disquisitions concerning volcanoes, which are not of so serious a nature, or so interesting as part of the foregoing disquisitions, being such as have more regard to truth than utility. One of the principal motives which induced me to write any thing concerning the mineral kingdom was, to attempt to obviate errors, and to set the world right in many particulars, and also to lay a foundation, and give a clue to assist young naturalists in the study of this important branch of natural history.

I saw, that false facts and absurd conclusions from them were daily imposed upon the world; and as I knew this, I could not justify myself without detecting such errors, and communicating my knowledge of a great many facts which have been misrepresented by several eminent writers, who have neither taken the pains, nor had the opportunities of seeing so much of the mineral kingdom as I have; and some of them are too much attached to a favourite system to acknowledge Truth, if they saw her adorned with all her excellencies and beauties. How far I have succeeded in this part of my plan and intention, must be determined by the judgment of the candid naturalist.

When gross mistakes and absurd conclusions are published by men of eminence in the republic of letters, as indubitable facts, they have very pernicious effects, by encreasing difficulties in the knowledge of Nature, and establishing scepticism, and, by the sanction of great names, such erroneous opinions become the vogue; and, therefore, every novice will say something on that side of the question, although he knows very little about the matter.

I have thoroughly investigated and made myself master of every thing I represent as fact. I wish that all the modern writers about the concerns of the mineral kingdom had done so likewise.

There are two fossil bodies, which are claimed by many, as only belonging to volcanoes, namely *basalts* and *tufa*, which really and truly belong to the mineral kingdom in general. These I will endeavour to rescue from this unjust detention, and to restore them to their proper stations in the system of nature. Because basalt is often found about volcanic mountains, this circumstance is adduced as a proof of its being crystallized by the fire of the volcano; but I affirm, that real basalt is a real stone, and part of a real stratum, the exterior parts of which are frequently formed into columnar and glebous figures, which happened at first by drying.

However, I will not pretend to say, that some of the curious gentlemen, who carefully examine volcanoes, may not see some fragments of basaltine rocks which have fallen from the summit or sides to the bottom of a crater, and which may be thrown out again by eruptions of the volcano, with real marks of fire on them; but this accident does not alter the nature of things. Basalt is still a real stone, which belongs to a very numerous and very extensive class of strata; the natural history of which I have so fully explained formerly, that little or nothing more need be said about it here; only we may safely and fairly observe in general, that the modern gentlemen of the Pyrrhonian system are as famous for drawing inferences from a shallow knowledge of their subject, when treating of the mineral kingdom, as any set of philosophers that ever appeared in the world.

I have made it evident by ocular demonstration, that the basalts are as much, and as really rocks and strata, as any rocks and strata in the superficies of our globe; and as such, they constitute a considerable and a material part in the constitution of this great fabric, having as regular strata above and below them as any in the superficies of the globe, and spreading as wide, and stretching as far in the longitudinal line of bearing, as any of their concomitant strata; and, therefore, we cannot allow their being called lava, any more than the other strata found above and below the basalts; and if some of them, namely the strata of coal, were to come in contact with burning or running hot lava, they would soon make such a conflagration in that part of the globe, as would produce more lava, not like basalts, but like dirty slags, such as we have seen where seams of coal have been accidentally set on fire. Basalt, as I hinted before, is a real stone, composed of different grains and particles of other stones, such as principally of quartz and schorl, with some admixture of iron and mica, and less or more earth, according to the perfection or debased quality of the stone.

Now, the quartz and schorl approach in their natural state to a crystalline stone, that is, they have the fineness and purity of crystal; and although quartz is found of several colours, and schorl, as far as I know, always black, yet nevertheless they both produce the finest transparent uncoloured crystal when vitrified, unless there is some mineral admixture to colour it. In short, basalt is found, by chemical experiments, and by every other examination, to be as really and truly a stone as any other rock in the world. But I need not proceed. The strata of basaltine rocks keeping their stations in the superficies of our globe in every country where they are found; their spreading as wide, and stretching and dipping down as far, as the concomitant strata which are placed above and below them; and strata of coal being found and wrought both mediately and immediately above the strata of basalt, are as satisfactory and convincing as a thousand demonstrations, to prove that it is not lava, or crystallized from fusion by fire, but natural strata of rock; and which strata of rock bear a considerable bulk, and are regularly placed among the several other strata which form the stupendous structure of the solid superficies of our globe; and if any man doubt the truth of this assertion, he may see it with his eyes in the neighbourhood of Bo-ness, in many places among the hills upon both sides of the road betwixt Bo-ness and Bathgate, almost all over Fife, and in several other parts of Scotland; and, moreover, there are as regular and as beautiful columnar basalt in the Bathgate hills as can be found in any country, with strata of coal and of limestone above and below the stratum of columnar basalt. This is not a singular phenomenon in this country, strata of basalt being very common in the coal-fields of the Lothians, Fife, Ayrshire, &c. They are also frequently found in extensive strata in their proper stations among their concomitants, in the north of Scotland, where there is no coal; which facts are conclusive, and prove beyond a doubt, that basalt forms as real, and almost as extensive strata of rock, as any other in the structure of the superficies of our globe.

I will now make some inquiries concerning *tufa*, which some of our modern naturalists say is only produced by volcanic fires, which I deny. But in order to point out the true origin, and to illustrate the natural history of *tufa* or *tofus*, it may be proper for me to take a cursory view of some stallactitical productions, which are so near of kin to tufa, that they are originally of the same family; and it is pretty generally known, that the stallactites are stony concretions.

That water percolates the pores, and passes through the fissures of the strata, is a well known truth; and it is equally well known, that water carries along various particles in its subterraneous motion. While this subterraneous water is excluded from the external air, it continues to carry about the terrene particles that are combined or mixed with it; but when it issues out into the external air, or into any cavern or subterraneous receptacle into which air has access, then the quantity of water is immediately lessened by evaporation, and of consequence, it must drop some of the minute fossil particles and leave them behind. So long as the subterraneous water is excluded from the action of the external air, it may be so perfectly combined with various heterogeneous particles, as to appear to be nothing but a pure transparent liquid, although it contains a considerable quantity of earthy matter. "When air, says Lord Kames, comes in contact with water, it proves a solvent," and melts it down to steam, or particles small enough to rise buoyant in the atmosphere; which doctrine is certainly true: and I think this as clear and evident as any thing of the kind can be, and it helps to explain the process of nature in forming petrifactions, concretions, and some species of sediment, especially those of the ochreous kinds.

f water were always to remain in equal quantity and force as when it took up the terrene particles in its subterraneous passage, it would leave none of them behind: They would all be carried forward to the sea. But the contrary is the fact: The water is in part dissolved into particles inconceivably small, or evaporated, and the stony particles are left behind in caverns, &c. which particles form, by the gradual accretion of matter, the stallactites, and other stony concretions. I have seen old deserted mines and coal-works contain great quantities of those productions; and in some places, they form in much less time than I imagined before I saw it with my own eyes.

A great many subterraneous caverns are replenished with great quantities of these stony concretions; among which, the caves of Nigg, at the sea side, a little way to the east of the entrance into the bay of Cromarty, are not the least remarkable. All the stallactites in those caves are calcareous, and of a very fine texture. Either some corroding waters passing through beds of lime dissolve part of it, or else common water, percolating the pores and crannies of the strata, finds the lime by the way in small particles, which it carries along; but when the water issues out of the roof and sides of such caverns, it is evaporated slowly, by coming in contact with the air in the cave, and the stony particles are left behind, and lay the foundation of those curious stallactitical productions, which are still enlarging and improving by the continual accretion of matter; that is, by the minute particles which are carried and left by the water. While the stony matter is in a fluid state, before the water has quite deserted it, it is spread out slowly by the remaining water over all parts of the mass actually forming, and then the residue of the water evaporates slowly, and leaves the stony matter there upon the mass; by which process petrifactions and stony concretions are formed, and gradually come to perfection. The greatest and most material difference between these concretions and those of another quality is this: All the stallactitical bodies in the caves of Nigg, and many others which I have seen, are composed of calcareous particles, which effervesce with acids, and produce lime when calcined. The other concretions are formed by the same process of nature, of vitrifiable particles, which do not effervesce with acids, or produce lime by calcination, but are easily vitrified or melted to glass or slag.

There are great quantities of the concreted substance called *tufa* in many parts of Scotland. Tufa is always found upon the surface of the earth, unless it should happen by accident that some adventitious cover is thrown above it. It is commonly situated below some small, slow, or weak springs, and it generally appears in a whitish or ashen-grey coloured, porey, and moderately light marle-like substance, frequently spread out pretty wide and high, resembling at a distance some whitish mishapen rocks. I have seen much of this concreted substance wet, spungy, and soft as mud, while the water which lodged the particles was partly mixed with it before it had time to be completely evaporated; and I have seen it dried and indurated to various degrees of hardness, and profitably burnt for lime. The process of Nature, in the formation of this substance, is to be explained upon the same principles as the stallactites. A small rill or quantity of water issuing out to the surface of the ground, and carrying stony particles with it, part of the water is immediately evaporated so soon as it comes in contact with the external air. By this evaporation, the rill of water is continually diminishing as it advances forward from the aperture out of which it issues, and creeps among the grass along the surface of the earth; and consequently the stream is retarded in its motion, and some of the stony particles are at first lodged in the grass or otherwise; and when these first lodged particles are accumulated to any thing of a considerable mass of tufa, there becomes at last little or no run of water at all, it being detained in the chaotic mass of the forming matter. A considerable part of the most recent sediment frequently remains for some time wet, soft, and spungy, like mud, in which all the water that strains out of the ground or rock is absorbed and detained, until it has time to be evaporated by degrees, and the concreted mass to acquire firmness and consistence. I have frequently seen tufa forming immediately beneath the side of lime-rocks, where the quantity of water was so small, as only to slide gently down the rock, without forming a rill; and where the water issued out in such quantity, as to form a rill or streamlet at the foot of the rock, I have seen the mass of tufa accumulated high and wide, and stretching to a great distance below the rock; and it is worthy to be remarked, that where the rill of water issuing out of a lime-rock, or elsewhere, is so strong and copious, summer and winter, as to be able to carry all the stony particles away with it in a full collected current, no mass of tufa shall be accumulated in such places; but the bottom and sides of the rill, or channel of the little current, is generally covered with a whitish crust, by some of the stony particles sticking to every thing as they pass along.

A novice in the natural history of fossils may at first sight doubt the truth of the assertion, that stallactites and tufa have the same origin and efficient cause, from seeing a very distinguishable difference in the internal and external appearance of the masses of both kinds; and I confess, that the difference of the inner and outer appearance of the masses of both kinds; and I confess, that the difference of the inner and outer appearance of the masses of both is abundantly obvious; and, therefore, for the satisfaction of such, I will explain the natural reason of this apparent difference.

I observed before, in general, that this difference in appearance is occasioned by the different situations where they are formed; but I must be more particular and explicit.

Below ground, the stalactites in caverns are generally found hanging attached to the roof, or adhering to the sides of the cave, or formed upon the floor, by drops of water falling directly down from the roof. In that situation, the water generally issues out in very small quantity; and in its descent from above, it glides gently and smoothly down the surfaces of the masses which are forming. The exhalation or evaporation of the water goes on but slowly in that situation, there being perhaps little air admitted, and that little comparatively damp and ineffectual for want of free circulation; of consequence, the particles of matter, which are very small, can be laid on the increasing mass but leisurely, and, the water still gliding down, lays these small particles close together upon the mass, and keeps the surface of it continually as smooth and glossy as if it were polished. In the formation of tufa upon the surface of the earth, the evaporation and waste of the water, on the contrary, are more copious and hasty, being exposed to the external air and sun; and, of consequence, the terrene particles are precipitated more hastily, and in much greater abundance; and these particles, which are large, are more rudely propelled and huddled together into an irregular confused mass, which swells and gorges in different parts, by the remains of the water being detained in it, as in snow in a rainy day, which of consequence must produce a loose porous misshapen mass of petrifaction. When one quarter of the general mass of tufa is grown high and extensive, by the stagnating and gorging of the water in passing through the newly precipitated stony matter, as formerly mentioned, the water then turns aside from some part of it, and immediately begins to make an addition to the bulk of the accumulated mass upon the side it now runs to, in the same manner as above-mentioned; and then that part of the mass which the water has newly left, gets time to dry and harden, by degrees, as the water is strained and evaporated out of it. I have seen some parts of large masses of tufa, which were high above the present course of the water, dried and indurated to such a degree, as to make them difficult to be quarried for burning to lime, although such parts, when first formed, or rather while forming, were nothing better than a puddle of calcareous mud, much resembling half snow half water in a rainy thaw.

Having abundantly unfolded the natural history of stalactites and tufa, I will now proceed to point out a few of the many places where tufa may be found. There is some of this substance beneath a spring in the Hill of Carlops, about twelve miles south of Edinburgh, upon the north-east side of the hill, and pretty high up. Some of it contains a considerable quantity of moss and grass, which has been enveloped by the stony particles, and it is preserved in the masses of the tufa so perfectly as to look like petrified moss.

There is a quantity of tufa near Troup, in Aberdeenshire, situated near a lime-kiln between the house of Troup and the village of Gardenstoun. I have seen tufa in the island of Isla in several places, particularly near the south or south-east of the limestone field in that island, where I distinctly remember to have seen one very large parcel of it accumulated like large misshapen rocks*. Now, it cannot be pretended that there are any volcanic symptoms near either of those places.

* The mineral substance, here called *tufa* by the Author, is usually known by the name of petrified moss, and is not uncommon in places where water flows over lime-stone. Such springs are called petrifying springs.—Editor.

Having now pointed out the true origin and nature of tufa, the application of what I have advanced on the subject in question is plain and simple. It is abundantly evident, even to the slightest inquirer, that the tufa has no more connection with, or relation to volcanoes, than to any other place where calcareous or other particles of stony matter exist; and are so situated, that they can be taken up and carried along by water, either into subterraneous caverns, or out to the surface of the ground.

Tufa may be found upon a volcanic mountain, in the near neighbourhood of a volcano, or of volcanic matter, as well as in any other place, where stony particles may be found and carried by water. Rain water and melted snow, percolating the strata of a volcanic mountain, and issuing out of any part of the sides or bottom of the mountain, may bring particles of stony matter out with it, and so tufa may be formed at the bottom or upon the sides of such a mountain. And again, the rain water and melted snow passing through the pores and crevices of the strata of a volcanic mountain, and falling down into the excavations of the volcano, may form tufa within the cavities of the mountain, if the water be combined with stony matter; and it is to be supposed, that the water will find plenty of it in passing through such extensive rocks as those of a large volcanic mountain.

If we look attentively into this matter, we can easily imagine the inside or excavations of a volcanic mountain to be a plenteous repository of tufa, where it is formed in greater abundance, and far more expeditiously, than it possibly can be formed any where upon the surface of the earth. Some of those mountains are known to have been volcanoes for two or three thousand years, and the quantity of lava and other rubbish thrown out of them by different eruptions is immense. Now, the depth and extent of the excavations of those mountains must be in proportion to the quantities of matter ejected from them. Upon some of these mountains, a prodigious depth of lava, ashes, and other rubbish, is spread out for several miles from the crater, and other apertures, out of which the several descriptions of volcanic matter are ejected: What prodigious excavations of consequence must there be within the bowels of such mountains! I am persuaded, that the fiery caverns of some volcanoes are much deeper, and extend much further from the original craters, than we generally imagine The extent of the excavated caverns, or their distance from the apertures, must be in proportion to the accumulated or diffused state of the veins of pyrites, or other volcanic fuel. The narrower and more confined these veins are, the further from the crater the subterraneous excavations must extend, to produce such immense quantities of lava, and other rubbish, which have been thrown out.

It is well known to mineralists, that pyrites, and other inflammable fossils, are oftener found in veins and strata, of no great thickness, than in vast accumulated heaps; but such veins and strata frequently extend far in the line of bearing; and this great length of the veins is the physical cause of some volcanoes advancing so far in the horizontal line, from the bottom of the original funnel, as sometimes to pass under the waters of the sea from the main land to an island, or *vice versa*; and it is the cause of eruptions sometimes in the waters of the sea, when a vein or stratum of volcanic fuel happens to come up to near the surface of the solids, under the water of the sea. This too is the real cause of the duration of many volcanoes. If the whole store of volcanic fuel were accumulated contiguous to the first volcanic aperture, the conflagration would be amazingly great and violent while it lasted; but it would soon consume all the fuel, though ever so great in quantity; but, according to the real constitution of things, or, in other words, according to the natural history of the mineral kingdom, a vein or veins, a stratum or strata of combustible matter, not many feet in thickness, may feed the internal fires for several thousand years; but then it is necessary that the fire make very extensive progress downwards, and in the line of bearing from the first crater of the volcano.

Now, it is easy to conceive, that this prodigious extent of excavation and length, of course must cut and intersect a great number of subterraneous springs and currents of water, which will let down a vast quantity of water into the several caverns and receptacles of the volcano.

In some places, not only large and copious springs, but even considerable rivulets, are drained by the progress of volcanoes; and every drop of the water so drained from the surface must go down into the excavations of the volcano. It is well known, that water, in its natural state, contains a considerable quantity of earthy, stony, or saline matter, &c. and the dried springs, rain water, and melted snow, percolating the pores, and passing through the crevices of the strata of a volcanic district, must carry down very much stony matter with it into the various parts of the excavations; by which means great quantities of tufa will be formed or produced, in a comparatively short time, by the immense heat of the volcano evaporating the water to steam almost as fast as it falls down. It is certain, that every drop of that water is evaporated, and goes off in steam; and, of consequence, the stony particles carried down by the water will be left behind, and tufa will be thus formed. When the heat of the volcano is great, the water will be evaporated, and fly off in steam with great rapidity; and, of consequence, as the stony particles cannot be evaporated, the subterraneous tufa will form with equal rapidity, and no doubt successive eruptions will sweep it out through the crater and other apertures, and lay it somewhere or other upon the face of the country in the neighbourhood of the volcano. It may be objected to me, that, in my history of stalactites, I stated, that those petrifactions only are formed in subterraneous caverns, but that tufa is not formed there, but above ground; which is true of ordinary caverns; but volcanic excavations are not ordinary caverns. In the cool receptacles of the mountains or cavernous shores of the ocean, the progress in the formation of stalactites is exceeding slow, because evaporation is slow, on account of the small quantity of air that is admitted there, and on account of the dampness and tardy motion of that small quantity; whereas, on the contrary, in volcanic caverns the quantity must be greater, a thousand times hotter, and, of consequence, in a thousand times quicker circulation, owing to the greater heat; and the great heat and quick circulation or motion of the internal air will occasion a prodigious quick evaporation, and of course the terrene particles must be huddled together very hastily, and left loose and porous in the form of tufa, resembling in texture a mass of wet lump-sugar or half melted snow; and as it is hastily formed in the cavities of the volcano, so may it be as hastily thrown out to the surface by different eruptions, and in the form of "liquid mud," as it is called; at the same time I am confident, that it was not the first matter that issued from Vesuvius, or from any other volcano, although it might flow out, or be ejected many times afterwards, when the excavations of the volcano became capacious and extensive enough to admit sufficient quantities of water for producing it. I might point out a great many ways how tufa may be formed in the neighbourhood of volcanoes, and yet it might happen to be produced in many other forms and situations, which I would not be able to conceive or explain, without investigating the circumstances upon the spot: but I do not think it necessary to say any more about the matter, as I imagine, that what I have advanced in explanation of the natural history of tufa, will be abundantly satisfactory to convince the unprejudiced naturalist, that tufa has no more to do with volcanoes than with any other places where terrene particles and water may be combined together, and afterwards either fall into the volcanic excavation, or issue out to the surface of the ground, in situations favourable for the production of that petrified matter.

From what has been said, it evidently appear that tufa is not a sufficiently solid foundation upon which to build any part of a hypothesis respecting the eternity or duration of the world, it being an adventitious substance, much of which is a recent production, is continually forming, and it will continue to be formed so long as the world endures in its present condition; and, therefore, it is not necessary after this for naturalists to associate the idea of volcanoes, or volcanic matter, with tufa; as it evidently appears, that it has no manner of relation to volcanoes, any more than to other places, which are favourably situated for its production. It is to be seen formed, and now forming, in ten thousand places upon the face of the earth, far enough from volcanoes, or from any volcanic matter. Tufa is to be seen formed and forming in at least a thousand different places in Great Britain; and there is no real symptom of a volcano ever having been within this island.

Perhaps some of these systematic gentlemen, who generally call in every thing to countenance a favourite hypothesis, may imagine, and they have asserted, that they see tufa beneath some of the real strata of native rock; but they should be a little more cautious than they often are of asserting too boldly what they are not sure of. Tufa may be found at the foot of a rock, and attached to it, and if there were any original cavern, it may be filled up with tufa; but it is never found between real and regular strata: and these gentlemen should remember, that there is such a degree of resemblance between some beds of clay and of marl, and other argillaceous strata, and also between some of the mineral soils, ochres, &c. and the tufa, as may be readily mistaken by such gentlemen as have not had opportunities of much accurate observation, and long experience, in matters relating to the mineral kingdom.

That fossil substance found upon or near the surface of the ground, called *puzzolano*, may happen to be subterranean tufa, composed of calcareous and ferruginous particles, burnt to a great degree in the furnace of a volcano, before it was thrown out by violent eruptions; and the great degree of heat it then suffered, with the mixture of iron it contains, may be the cause of the absorbent quality which it is known to possess; but as I am not very well acquainted with the puzzolano, I will say no more about it.

In this æra of learning and science, an inquisitive spirit of research, guided by philosophy, traverses the bounds of the universe in pursuit of knowledge, and new discoveries are daily made, for which all the tribute of praise and acknowledgment which the warmest gratitude can express, are due to many modern names, for the numerous local observations, and the many facts which have been communicated to the world relating to physics and antiquity, since the commencement of the eighteenth century. But it must grieve a benevolent man, who has more regard to truth than to system, when he sees so many men of learning and worth strenuously endeavouring to found and support a system of falsehood, absurdity, and nonsense, in opposition to the phenomena of heaven and earth, and in flat contradiction to the opinion and belief of sober reason and sound philosophy in all nations, from Socrates to Boyle:—I might say, from the beginning of the world until now. Several modern philosophers may justly be termed innovators in physics and chronology.

They pretend to prove to a demonstration, that the world itself is of a much older date than the earliest accounts which are handed down to us from all antiquity, written or traditional; and some of them will allow it no beginning at all, for no other good reason that I know of, but because they did not see the beginning of it. I will relate one pretended fact, which has been lately discovered and made use of, to overthrow the chronology of the Pentateuch, and indeed all ancient chronology whatever; which fact is said to be well attested. It is related in Brydone's tour through Sicily and Malta. I give it in his own words:

"When we came near the sea in the neighbourhood of Catania, I was desirous to see what form the lava had assumed in meeting with the water. I went to examine it; and found it drove back the waves for upwards of a mile, and had formed a large black high promontory, where before it was deep water. This lava, I imagined, from its barrenness, for it is as yet covered with a very scanty soil, had run from the mountain but a few years ago; but was surprised to be informed by Signor Recupero, the historiographer of Ætna, that this very lava is mentioned by Diodorus Siculus to have burst from Ætna in the time of the second Punic war, when Syracuse was besieged by the Romans. A detachment was sent from Tauraminium to the relief of the besieged. They were stopt in their march by this stream of lava, which had reached to the sea before their arrival at the foot of the mountain, and entirely cut off their passage, and obliged them to return by the back of Ætna, upwards of an hundred miles about. His authority for this, he tells me, was taken from inscriptions from Roman monuments found in this lava, and that it was well ascertained by many of the old Sicilian authors.

"Now, as this was about two thousand years ago, one would have imagined, if lava have a regular progress in becoming fertile fields, that this must long ago have become at least arable. This, however, is not the case; and it is as yet only covered with a very scanty vegetation, being incapable either of producing corn or vines. There are, indeed, pretty large trees growing in the crevices, which are full of a very rich earth; but, in all probability, it will be some hundred years yet before there is enough of this to render it of any use to the proprietors. . . . . .

" Near to a vault, which is now thirty feet below ground, and has probably been a burial-place, there is a draw-well, where there are several strata of lavas, with earth to a considerable thickness over the surface of each stratum. Recupero has made use of this as an argument to prove the vast antiquity of the eruptions of this mountain. For if it require two thousand years or upwards to form but a scanty soil on the surface of a lava, there must have been more than that space of time betwixt each of the eruptions that has formed these strata. But what shall we say to a pit they sunk near to Jaci of a great depth. They pierced through seven distinct lavas, one over the other, the surfaces of which were parallel, and most of them covered with a thick bed of fine rich earth. Now, says he, the eruption that formed the lowest of these lavas, if we may be allowed to reason from analogy, must have flowed from the mountain at least fourteen thousand years ago."

I WILL not pretend to dispute the date when the promontory was formed by the lava, nor do I question the authenticity and accuracy of the experiment of the pit. I give the same credit to both which I do to other historical facts; but I have several things to observe concerning the conclusions drawn from those facts.

In the first place, I would ask the gentleman who was present at digging the pit, if he be certain that the lava did decay at all, so as to be converted into soil? I think the case very doubtful, especially if the lava were perfect or thoroughly vitrified; and their finding such a number of strata of soil and lava alternately, makes it still more doubtful.

Is it well ascertained, that the surface of a stratum of lava decays and moulders down before the centre? If they say it is, I then ask how they came by this certainty? Is it by observation and experience? If it be, then it must happen within a much shorter period of time than the one laid down to calculate the age of the world by, as no men in these ages live up to two hundred years.

But it is well known to all those who are in the least acquainted with the history of volcanoes, that prodigious showers of ashes are frequently thrown out of the craters, and sometimes to a great distance, producing a stratum of good soil at once, and as effectually in less than two score, as in two thousand years. That ashes, pumice, and other rubbish are very frequently thrown out of volcanoes, and spread wide over the face of the country, is too commonly known to admit of any dispute, and certainly these showers of ashes will fall upon beds of lava, as well as upon any other part of the country; and as the contiguous parts of the country next the volcano are generally covered with lava, the showers of rubbish and ashes have a greater chance to fall upon lava than upon any other ground. I made it evident before, that tufa is formed very expeditiously in the excavations of volcanoes; and I have all the reason in the world to believe, that there is a proportion of tufa in these showers of ashes.

There is no room to doubt of there being tufa mixed with the ashes; and this mixture will greatly enrich the composition, and hasten its conversion into good soil. Now, the situation of the above-mentioned promontory is not so favourable for acquiring a thick coat of soil in so short a space of time. Its distance and site may not be convenient for receiving showers of ashes and rubbish; and moreover, a promontory is so exposed a situation, that every thing is blown from it. I have seen the soil evidently decreasing upon some promontories in Britain, and mostly all blown off the extremity of several in Aberdeenshire, Caithness, &c. But I need not multiply words. It is obvious to every unprejudiced inquirer who will examine circumstances, that there might be a greater depth of soil made upon the one place in less than two-score of years, than upon the other in much more than two thousand. When I look seriously into this subject, I cannot help admiring the credulity of those gentlemen in building so high upon such an insufficient foundation. Some of these celebrated facts are founded upon single local circumstances, are but slightly attested, and it is impossible to prove the truth of the conclusions. They are founded upon hypothesis alone; and, moreover, the fact I hinted before of showers of ashes, &c. mixed with tufa, overthrows the hypothesis, and makes all their reasonings upon it chimerical and absurd. It is highly probable, that the boasted experiments or pits were made on purpose to countenance an established persuasion. I care not what name or figure any one of those gentlemen bears in the world. He is a man, and so am I, and as such I am as deeply interested, as an individual, in all the concerns of this world, and that which is to come, as he is; and, therefore, I have a right to examine the truth of what he proposes to me upon so interesting a subject, and to detect the fallacy of his propositions, if it be in my power, and I think it my duty so to do.

In this freedom of inquiry, I will venture to suggest, that if any man, or number of men, were to take the history of the experiments upon the lava in their hands, proceed to the spot, and dig a hundred pits through all the strata, I doubt if their discoveries shall correspond with the history, or come any thing near it; no, not in one single place out of the hundred; and the reason is plain and obvious. Volcanoes, with their eruptions and lava, are not regular operations of nature, but dreadful accidents, attended with the most horrible confusion and disorder. It is an indubitable fact, attested by a multitude of unprejudiced eye-witnesses, that eruptions of volcanoes are sometimes exploded with such amazing violence, as to force a prodigious quantity of matter high up into the air; and, at other times, these astonishing explosions throw the matter many miles off into the sea, or on to the land, which frequently makes great havock and devastation.

When lava issues out, it is attended in its appearance and consequences with still greater horror and destruction. Fields, woods, stone-walls, and populous towns, are all irresistibly driven before it. In such horrible confusion, it is impossible to ascertain the numberless accidents that may happen. All the vegetable and combustible substances that come in contact with the fire, will be consumed at once; but the upper soil of the desolated fields will be driven before the prodigious weight of the fiery deluge, and thrown in all directions. Some parcels of it may be inclosed or overwhelmed betwixt layers of burning matter, and other parcels of it may be surrounded by meeting currents of fluid fire, and form little islands or nests of soil, which will be overflowed and buried by the next deluge of fire that issues out, perhaps that very day, or the next, or the next year. And will any sober man pretend to draw important inferences from such devastations and utter confusion as this, and call them well attested facts? Their credulity appears to me as astonishing as the confusion upon which they build their inferences, if they really be deceived by such false lights; but if they are not, why then the gentlemen are pleased to divert themselves with our ignorance and credulity. To think them serious, is but a very poor compliment to their penetration and philosophy. But I take up too much time in exposing such vague and fallacious conclusions. It is fully evident from what has been said before, as well as from some parts of their own histories of volcanoes, that the phenomena which they discover, and build upon, might all happen within fourteen hundred years, as well as in fourteen thousand years twice told.

APPENDIX

BY THE EDITOR.

In the preceding Work, it seems to have been the view of the Author to enter fully into the detail of facts, relative to two very important objects of geological investigation, namely, the natural history of coal and of metallic veins. His situation and pursuits, during great part of his life, afforded him every facility of extensive observation in that department of geology, and rendered the knowledge of those objects more familiar than that of others of a kindred nature. This will probably account for many deficiencies, and some obscurity, in the discussion of different subjects less immediately connected with the two great objects of investigation above alluded to. The Reader, who is at all acquainted with the present state of geological knowledge, will be at once aware of what I have now stated; and, considering the view which seems to have guided the Author in his researches, the reader, who shall expect in his Treatise a complete system of geology, must be disappointed. But, besides, it would be uncandid and unjust to forget, that since the time in which the Author wrote, innumerable facts have been discovered, and a great body of information has been accumulated in the science of geology, of which he could not avail himself. The object of this Appendix is to supply the deficiencies and omissions which were unavoidably occasioned by the scantiness of the Author's materials, and to lay before the Reader as complete a view of this department of natural history as the limits necessarily assigned to it, and the present state of our knowledge, will admit.

INTRODUCTION.

Before proceeding to the consideration of the nature of the materials of which the surface of the earth is composed, and the manner in which they are distributed, which are more peculiarly the objects of the present investigation, I shall employ a few preliminary observations in noticing some general facts relative to the history of the earth. The facts now alluded to refer, 1. To the *Figure of the Earth*; 2. *Its Density and Magnitude*; 3. *The Inequalities of its Surface*; 4. *Proportion of Land and Water*; and 5. *The Constituent parts of Minerals*.

1. *Figure and Magnitude of the Earth.*—The figure of the earth is nearly spherical. The proofs which are usually adduced to establish this fact, are derived from observations made on the sailing of a ship, as it leaves or approaches to the land; on eclipses of the sun and moon; the rising and setting of the sun, moon, and stars; going or sail-

ing in a direct line to the north or south; and, lastly, sailing round the globe. When a ship sails from the land the hull first disappears, and next, as the distance is increased, the lower sails, and last of all the top of the masts: But when the ship is approaching to the land where the spectator is placed, the top of the masts is first seen, next the sails, and last of all the hull appears. The shadow of the earth, on the face of the moon in eclipses, is always circular, in whatever way that shadow may be projected, and whatever may be the variation of its diameter, arising from the greater or less distance from the earth. The shadow therefore being circular, the body projecting it must also be spherical. The rising and setting of the heavenly bodies afford another proof of the spherical figure of the earth. The sun, moon, and stars, rise and set sooner to the eastward of any given place on the earth's surface than to the westward of the same place. In going or sailing to the northward, the stars of the northern hemisphere become more elevated, while those of the southern hemisphere are more depressed. The spherical figure of the earth is also fully established by ships having sailed round the globe.

The sphericity of the globe being admitted, a great deal of investigation and discussion has taken place to determine whether it should be considered as a perfect sphere, or what were the deviations from this form. It was observed, that the vibrations of the pendulum were slower in places near the equator, but became quicker in approaching towards the poles; and hence it was concluded, that the places about the equator were farther removed from the centre of the earth than the places near the poles, where the vibrations of the pendulum were found to be quicker; and that the figure of the earth must therefore approach to the shape of an orange, or an oblate spheroid, generated by the rotation of an ellipse about its shortest diameter. This subject engaged the attention and profound physical knowledge of Newton and Huygens; and since their time, has exercised the sagacity and mathematical skill of many eminent philosophers in tracing the cause, and in ascertaining the amount of the difference between the polar and equatorial diameters of the earth. According to the calculation of Newton, and supposing the density of the earth to be uniformly the same throughout, the diameter at the equator is to the diameter at the poles as 692 to 689, or nearly as 230 to 229; or, according to others, as 215 to 214. Proceeding on the same data, the greater or equatorial diameter is calculated at 7950 English miles, and the shorter or polar diameter at 7913, the difference between the two diameters being about 37 English miles.

The measurements of degrees of the meridian at the equator, and towards the north pole, still farther demonstrate the figure of the earth to be that of an oblate spheroid. And from these measurements, from observations and calculations, taking the mean of the whole, the magnitude is nearly as follows:

Diameter in miles	7958.
Circumference	25,000.
Superficies in square miles	198,944,206.
Solidity in cubic miles	263,930,000,000.

2. *Density of the Earth.*—The density of the earth has been calculated and deduced from the observations made by Dr Maskelyne on the mountain Schehallien in Perthshire, in Scotland. The attraction of that mountain on a plummet was observed; and its mass, which consists of stone, was computed from a number of sections in all directions. Comparing these data with the known attraction and magnitude of the earth, the gravity or mean density is found to be as 9 to 2 of water; that is, the weight of the whole mass of the earth is $4\frac{1}{2}$ times greater than its bulk of water. The density of the earth thus discovered, being nearly double that of common stone, of which by far the greater part of the superficial parts, with which we are acquainted, are composed, has led to an inference, that the central parts are occupied by heavier substances than the stony matters of the globe, and probably by a large mass of metallic matters.

3. *Inequalities of the Surface of the Earth.*—The inequalities on the surface of the earth may be considered as one of its most striking features, and produce that agreeable diversity of scene and climate which arise from hill and dale, mountain and valley. But whatever be the grandeur and immensity of this natural scenery as it appears to the circumscribed view of the spectator, it sinks almost to nothing when compared with the magnitude of the earth, and does not proportionally exceed the elevations and depressions on the surface of an orange, or the particles of dust on a small artificial globe.

Mountains are sometimes found single, but are oftener thrown together in groups, or arranged in ridges or chains traversing a great extent of country, proceeding through a continent in a longitudinal direction, or assuming in their mode of distribution a crescent form. In ridges or chains of mountains, which run from north to south, the western declivity is abrupt, and the eastern gradual and gentle; but when the direction of the chain is from east to west, the south side of the chain is the steepest. The Cordilleras, which extend the whole length of South America, afford a good example of this fact on a large scale. The western side towards the Pacific Ocean is steep, but the ascent on the eastern side towards the Atlantic is gradual and gentle. The mountains which skirt the western shores of Britain present a steep and often precipitous aspect to the west, and a gentle declivity to the east. Salisbury Craigs and Arthur's seat, in the vicinity of Edinburgh, present a similar illustration in miniature, having on the east side a gentle slope, and nearly a perpendicular front to the west. The Pyrenees, which divide France from Spain, and run from east to west, are steepest on the southern side.

The height of mountains in different parts of the globe is various. Ben Nevis in Inverness shire, in Scotland, which is the highest mountain in Britain, is little more than 4300 feet above the level of the sea; Mount Blanc, one of the Swiss Alps, and the highest European mountain, is about 15,600 feet; and Chimborazo, the summit of the Andes or South American chain, rears its snowy head immediately under the equator to the astonishing height of 20,000 feet. But there is some ground for conjecture, that this extraordinary elevation is even exceeded by that of the mountains of Tibet, situated far in the interior of the extensive Asiatic continent, some of which are covered with perpetual snow, but in latitude 35° N., and were seen at the distance of 300 miles*.

4. *Proportion of Land and Water on the Surface of the Earth.*—The proportion of the superficial ex-

* Turner's Embassy.

tent of the globe, occupied by land and water, has been variously estimated. According to Buffon and some other philosophers, assuming the existence of a southern continent, which seems now to be fully disproved, the proportion of land and water is nearly equal. But it has been ascertained by the observations and calculations of others, that the proportion of the surface of the sea is to that of the land as two to one. To settle this point by actual experiment, an ingenious contrivance has been thought of: The paper which covers a terrestrial globe being as nearly as possible of equable thickness, and carefully divided with a pair of scissars, the parts representing the land and the water separated and weighed, indicate the proportion of two thirds of the latter, and one third of the former.

The depth of the sea has not been more accurately determined than its extent of surface. It has never been actually sounded much deeper than a mile; but so far as observation goes, the depth seems to increase in proportion to the distance from the coast. Near the land the depth of the sea bears some relation to the height of the mountains in the neighbourhood; and if this hold through the whole extent of the ocean, its greatest depth is not more than four or five miles; the most elevated mountains do not exceed this height above the level of the sea. The bottom of the ocean, so far as it has been explored, bears a striking resemblance to the surface of the dry land, exhibiting a varied scene of rugged rocks, lofty mountains, and deep valleys.

Attempts have been made to determine the quantity of water in the ocean; but it is perfectly obvious that the result of calculations, proceeding on data so extremely uncertain, cannot be very accurate. Taking the surface of the ocean at two thirds of the superficies of the globe, or 132,629,470 square miles, and supposing the medium depth of the sea to be one fourth of a mile, the quantity of water will amount to about 33,157,367 cubic miles.

5. *Constituent Parts of Minerals.*—The wonderful diversity of form, and rich variety of colours, which are exhibited in the productions of the mineral kingdom, would at first sight lead to the supposition, that the number of constituent parts which enter into their composition is immense. But the researches of modern chemistry have discovered only a few simple substances, which being variously modified and combined, afford that splendid display of mineral riches with which the repositories of the objects of this department of nature are stored. The number of simple substances, that is, such as seem unsusceptible of farther decomposition, which have been hitherto detected in mineral bodies, amounts to about

forty-seven, as will appear from the enumeration in the following Table:

Oxygen	Magnesia	Lead
Azote	Alumina	Tin
Hydrogen	Silica	Bismuth
Carbone	Yttria	Antimony
Phosphorus	Glucina	Cobalt
Sulphur	Zirconia	Nickel
ACIDS.	METALS.	Manganese
Muriatic acid	Platina	Molybdena
Fluoric acid	Palladium	Arsenic
Boracic acid	Rhodium	Tungsten
ALKALIES.	Iridium	Titanium
Potash	Osmium	Uranium
Soda*	Gold	Tellurium
EARTHS.	Mercury	Chromium
Lime	Silver	Columbium
Barytes	Copper	Tantalium
Strontites	Iron	Cerium.

Of the simple substances above enumerated, it may be observed, that they are rarely found in

* Potash and soda have been decomposed by means of galvanism; and their constituent parts seem to be oxygen and a metallic base. But as the nature and properties of this metallic substance are yet very imperfectly known, I have still arranged them with the simple substances. Lime, barytes, and other earths, which approach to the alkalies in some of their properties, and therefore called *alkaline* earths, are supposed also to be compounds.

nature uncombined, or in a state of purity. Oxygen is frequently combined with many of the metals in the state of oxide, as in the case of iron or tin, with which it forms the oxide of iron or tin, a common ore of those metals. The product of azote with oxygen is nitric acid, which latter with potash constitutes native nitre or saltpetre; and the product of azote with hydrogen affords ammonia, which in combination with muriatic acid forms native sal ammoniac. Water is a compound of hydrogen and oxygen. Carbone, phosphorus, and sulphur, are severally the bases of acids, which enter largely into the composition of various earthy and metallic salts. Muriatic acid is a component part of common salt and sal ammoniac. The beautiful mineral production known by the name of fluor or Derbyshire spar, consists of fluoric acid and lime; and boracic acid with magnesia forms boracite or borate of magnesia. Potash and soda have been detected in intimate union with stony bodies; and the earths are usually combined with each other, and with acids, or are slightly contaminated with metallic matters. The metals too, as they are presented to us by nature, rarely appear in a state of perfect purity; for they are either alloyed with each other, or combined with oxygen forming oxides, or with acids forming salts; and in the various states of combination now specified, they are seldom entirely free from some portion of earthy substances.

The connection of mineralogy and geology has been not unaptly compared to that which subsists between the alphabet and words of a language; and as the knowledge of the letters is previously necessary to understand the words and structure of language, so, to have a distinct conception of the structure of the surface of the globe, it is essentially requisite to be acquainted with the nature and characters of the objects of which it is composed. This is the peculiar province of mineralogy; of which it is proposed to give a slight sketch, before proceeding to consider the general distribution and relative position of mineral substances. The history of some of the more important objects of the mineral kingdom, particularly coal and metallic substances, will next occupy our attention. The disturbances on the surface of the earth, occasioned by earthquakes and volcanoes, and the causes which are supposed to operate in the exhibition of those awful phenomena, will afterwards be treated of. And, lastly, it is intended to take a short view of some of the theories which have been proposed to account for the formation and distribution of mineral substances. These topics will form the subjects of the following Chapters.

CHAP. I.

OF MINERALOGY.

THE objects of the Mineral Kingdom, from the peculiar view under which they are considered, are arranged into two great divisions; the *first*, including simple minerals, or such as appear, from their external characters, to be of a homogeneous nature; and the *second*, comprehending compound minerals, or aggregates of two or more simple substances united in the same mass. Quartz, feld-spar, and mica, as they appear to the eye, are homogeneous substances, and therefore are denominated *simple minerals*; but when they are united into the same mass, constituting granite, the aggregate thus formed is a compound mineral. According then to this arrangement I shall, in the following sections, first consider Simple Minerals, and, secondly, Compound Minerals or Aggregates.

SECT. I.

OF SIMPLE MINERALS.

SIMPLE minerals, without regarding their mode of distribution, or relative position, as they exist in the earth, but considered as a group of unconnected individuals, have been divided, partly according to the nature of their constituent parts, and partly according to their external characters, into four classes, viz. I. Earths and stones; II. Salts; III. Combustibles; and, IV. Metallic Ores. But before attempting the following brief sketch of mineralogy, it ought to be observed, that it is far from my intention to give a full description of the objects which it embraces; for this, and for the elements of this department of natural history, I must refer to the works which are professedly written on the subject. I propose, therefore, to notice chiefly those minerals which are remarkable, either on account of some peculiarity of character or composition, or which, in a geological point of view, hold a conspicuous place on the surface of the earth.

CLASS I.—*Earths and Stones.*

The minerals belonging to this class are usually arranged into genera, the character of which is taken from the earth which is predominant, or is supposed to be predominant; for it will appear that minerals are sometimes arranged under one genus, which are chiefly, and in some cases almost entirely, composed of an earth belonging to another genus; but this arises from the resemblance in their external characters.

GENUS. 1.—*Zircon**.

The species belonging to this genus are chiefly remarkable, as they contain zirconia, a peculiar earth, from which the name is derived. There are two species, zircon and hyacinth, which are found either in rounded fragments, or crystallized, in Ceylon, France, and Norway. They are composed of zirconia 70 to 66; silica 25 to 31; oxide of iron 1 to 2. The natural repository is little known.

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* The diamond is usually placed in systems of mineralogy at the head of simple minerals, and constitutes the first genus of this class; but as its combustible nature has now been completely established, the history of this precious stone will be more properly introduced in the class of combustibles.

Genus 2.—*Siliceous.*

This genus, from the abundance of the earth from which it derives its name, contains a great number of species.

Chrysoberyl.—This mineral, which is greenish and yellowish, and sometimes exhibits changeable colours, is ranked with precious stones. It is found in rounded grains, or crystallized, in Ceylon and Siberia, and is composed of alumina 71, silica 18, lime 6, and oxide of iron 1·5, but of its repository nothing is known.

Chrysolite,—found in Bohemia and the Isle of Bourbon, in fragments or crystallized, is composed of silica 38, magnesia 39, oxide of iron 19. Crystallized varieties have been found in a kind of lava in the Isle of Bourbon.

Olivine.—Olivine in its constituent parts approaches to the preceding. It is chiefly in rounded pieces, but sometimes also crystallized. The rounded pieces are usually in the cavities of basalt, as in the basaltic rocks of the Giant's Causeway in Ireland, where I have collected specimens of this mineral.

Coccolite—exists in angular grains, which have some appearance of crystallization; is composed of silica 50, lime 24, magnesia 10, iron 7, manganese 3, alumina 2, and is found in iron mines in Sweden and Norway.

Augite—resembles the preceding in the nature and proportions of its constituent parts, and is found regularly crystallized in basalt, in Bohemia, Hungary, and Arthur's Seat near Edinburgh.

Vesuvian—exists either in masses or crystallized, and is composed of silica 35, lime 33, alumina 22, iron 8, and a little manganese. Being found in limestone near Vesuvius, has led to the supposition that it has been ejected unchanged from the volcano; but in Siberia it is imbedded in steatites, and mixed with crystals of magnetic iron.

Leucite—is usually crystallized, and is a singular mineral, not only as it exists seemingly unchanged in the real lava of Vesuvius, but also on account of its constituent parts, which are silica 54, alumina 24, potash 21. It is also met with in basalt in Italy and Bohemia.

Garnet,—including black garnet, which has hitherto been only found near Rome, precious and common garnet, and pyrope or Bohemian garnet, is usually crystallized, and is composed of silica 35 to 40, alumina 6 to 20, lime 3 to 30; iron and manganese 16 to 36. The only exception is, that the Bohemian garnet has not been found crystallized, and contains 10 parts of magnesia. The repository of the garnet is usually micaceous schistus, gneiss, and other primitive rocks. It is not uncommon in most countries.

Grenatite—is composed of silica 33, alumina 44, lime 4, iron 13, and manganese 1; is usually crystallized, and is found in micaceous schistus, in Switzerland, France, and Spain.

Ceylanite—is a crystallized mineral, found in the cavities of the lava of Vesuvius, and in basaltic rocks on the Rhine; is composed of alumina 68, magnesia 12, silica 2, iron 16. It is also met with in Ceylon, from whence it has its name.

Spinelle—is a precious stone of considerable estimation; is found in rounded grains or crystallized, in Ceylon and Pegu, and is composed of alumina 74 to 82, silica 15, magnesia 8, iron 1·5, a small proportion of lime, and in some specimens chromic acid 6 parts.

Sapphire—is a highly valued precious stone, of which the finest are brought from Pegu and Ceylon; but it is also a native of Bohemia and France. It is either in fragments or crystallized, of a fine blue colour of various shades, and is composed chiefly of alumina, as in the following proportions of the constituent parts of specimens analyzed; alumina 92 to 98, silica 0 to 7, iron 1.

Corundum, *adamantine spar*, and *emery*,—which are usually regarded as distinct species, might very properly be considered as one. They are extremely hard, found in masses or crystallized, and composed of alumina 84 to 89, silica 3 to 6, iron 2 to 7. Corundum forms part of a hard rock near the river Cavery, south of Madras, and is also met with in China and Ceylon; adamantine spar has been only found in China; and emery in different parts of Europe and South America.

Topaz—is usually crystallized, and is met with in different parts of the world, as in Siberia in graphic granite, accompanied with beryl, quartz, and garnet; in common granite, as at Zinnwald; and forming part of a rock called from this *topaz rock*; such is the mountain Schneeckenstein in Saxony, which is composed along with the topaz of quartz, schorl, mica, and lithomarge. The constituent parts of topaz are alumina 47 to 50, silica 28 to 30, fluoric acid 17 to 20, iron 0 to 4.

Euclase,—which I notice chiefly on account of a peculiar earth *glucina* forming one of its constituents, is a mineral found hitherto only in Peru, and crystallized. It is composed of silica 36, alumina 19, glucina 15, iron 3. The repository is unknown.

Emerald,—has obtained from its fine green colour a high rank among precious stones. It is found in Peru in the veins and cavities of granite; and also in Egypt and Ceylon, and is composed of silica 65, alumina 16, glucina 13, oxide of chromium 3, lime 2, and some iron.

Beryl—is usually crystallized, and assumes the same form as the emerald. Its constituent parts are also nearly the same, excepting that in the emerald the colouring matter is chromium, and in the beryl iron. The repository of the beryl is chiefly granite, as the graphic granite of Siberia, and an indurated clay like jasper, where it is accompanied by quartz, feldspar, garnet, and tourmaline.

Schorlite or *Schorlous beryl*—is usually crystallized, and imbedded in granite and gneiss; and is composed of alumina 52, silica 37, lime 3, and by some analyses, fluoric acid 6.

Schorl,—including common schorl and tourmaline, is remarkable on account of the electric properties which it exhibits when heated; is commonly crystallized, and is usually found in primitive rocks, as those of granite and gneiss. The constituent parts are alumina 40, silica 34 to 39, lime 0 to 4, iron 12 to 20, manganese 2 to 3. The finest tourmalines are brought from Ceylon and Brazil; but this as well as common schorl is met with in Britain and other countries.

Pistazite,—sometimes called *glassy actynolite*, *acanticone* and *arendalite*, is commonly crystallized, and is composed of silica 37, alumina 21, lime 15, iron 24 to 17, manganese 1·5. It is found on the surface, and in the fissures of argillaceous schistus, as in Arran in Scotland, from which I have a specimen in fine acicular crystals. Its repository is also limestone, as in the Pyrenees. It is met with also in France and at Arendal in Norway.

Axinite or *Thumerstone*,—is found either in masses or crystallized in the veins and fissures of primitive rocks, and chiefly those which have a base of serpentine, as in the Pyrenees, France, and Norway. The constituent parts are the same as the preceding mineral, and not very different in their proportions.

Quartz—exists, either in masses, in rounded pieces, or crystallized. It is one of the most abundant mineral substances, and assumes a great variety of forms and appearances. Amethyst is quartz crystallized, and coloured with iron and manganese. Rock crystal is also crystallized quartz, and contains, besides the silica, a small proportion of alumina and lime. Arran stones and cairngorums, which are usually of a smoky colour of various shades, are supposed to derive it from iron or manganese. These are usually found in the cavities of granite mountains. Rosy red quartz, which is found in Siberia and other countries, owes its colour also, it is said, to manganese. Milk quartz constitutes beds in primitive mountains; and common quartz, which assumes various indeterminate forms, is one of the substances of most frequent occurrence in every kind of rock. It forms one of the chief component parts of primitive mountains; sometimes in entire beds, sometimes in veins, and sometimes composing whole mountains, as in the islands of Islay and Jura in Scotland. It is very common in stratiform rocks, constituting the base of sandstone and in alluvial soil, in rounded pieces, or in the form of sand. Prase is also a variety of quartz, having the form of rock crystal, and of a leek green colour, which is probably owing to some metallic impregnation, as it is found in metallic veins in Saxony. Ferruginous quartz or iron flint, which seems to derive its peculiar character from a large proportion of oxide of iron, is found in veins of ironstone in Saxony and England.

Hornstone—is found in masses and rounded balls. There are three varieties, splintery, conchoidal, and woodstone. The first and the second are met with in veins of primitive mountains, as in Sweden and Saxony, and in the island of Rona near Skye in Scotland, where it forms a considerable vein, traversing a gneiss rock. The constituent parts are silica 72, alumina 22, lime 6. Woodstone the third variety, seems to be wood retaining its original texture, and converted into stone by some petrifying process. It is found in insulated masses or rounded pieces, in Bohemia, Saxony, and on the banks of Loch Neagh in the north of Ireland.

Siliceous Schistus—constitutes extensive masses of rock, as in Saxony and Switzerland; and at Lead Hills in Scotland, and Carlops at the extreme boundary of the great coal field to the south of Edinburgh. It is chiefly composed of silica, with a small proportion of lime, magnesia, and iron. Lydian stone, which is known by the name of touchstone, being employed to ascertain the purity of gold, is a variety of siliceous schistus, and is found in similar places.

Flint—is a mineral which is found in angular fragments, or in globular masses, tuberculated, corroded, or perforated. Flint is chiefly composed of siliceous earth, having only a small admixture of lime, alumina, and iron, but not exceeding 2 *per cent.* Flint is rare in primitive mountains, but is most abundant in stratified rocks, particularly in beds of limestone, marl, and chalk, where it is disposed in parallel layers, as in the chalk beds in France and England, and in the limestone rocks on the north coast of Ireland. In an insulated mass of white limestone to the eastward of Port Rush, which I had an opportunity of examining, the balls of flint were disposed in layers with great regularity. When the bed of limestone is of no great thickness, there is only one layer of flints; but in thicker beds two layers may be observed, the one near the top, and the other near the bottom of the bed, and the layers have the same inclination as the strata of limestone. In consequence of the singular geological relations of this mineral, a great deal of discussion has been excited among naturalists to account for the mode of its formation and distribution.

Calcedony—exists in masses of various forms in rocks, known by the name of amygdaloid, as in Iceland and the Faroe Isles; in the north of Ireland, and in some of the western islands of

Scotland. Its constituent parts are silica 84, alumina 16, with some iron. Carnelian is considered as a variety of calcedony, and is found in similar circumstances, but of less frequent occurrence. Agate, which exhibits great variety, and is met with in great abundance in different parts of the world, is chiefly composed of calcedony, carnelian, and jasper, arranged and disposed in various ways, from which have been derived particular names, as fortification agate, landscape agate, moss agate, clouded, spotted, and radiated agate. Agates are abundant in different parts of Scotland, as in the neighbourhood of Montrose and Stonehaven, in the rocks near Dunbar, and in the rocks about Dunure, on the shore of Carrick in Ayrshire.

Opal—is a mineral of which there are several varieties. The precious opal, which is held in great estimation on account of its fine play of colours, is found in veins, nests, and grains, in an argillaceous decomposed porphyry, near Caschau in Upper Hungary, and at Freyberg in Saxony, where its repository is also porphyry. Its constituent parts are silica 90, water 10. The common opal is found in veins, chiefly in amygdaloid rocks, and sometimes, it is said, in granites and porphyries. Besides the water and siliceous earth of the precious opal, it contains a small proportion of alumina and iron. Semiopal is found in similar places with the former, but chiefly in granite and porphyry, and particularly in the veins of such rocks as contain silver. This variety contains a very considerable proportion of iron. The last variety, wood opal, is found in masses, and retains the form and texture of the wood, which is supposed to be penetrated with the stony opaline matter. It is found at Schemnitz in Hungary.

Menilite,—considered by some as a variety of flint or a semiopal, is found at Menil Montant, near Paris, in nodules, disposed in interrupted strata, in argillaceous schistus, which is interposed between the beds of gypsum. It is composed of silica 85, alumina 1, water and carbonaceous matter 11, with a little iron and lime.

Jasper—is divided into six varieties: 1. Egyptian jasper, which constitutes part of a breccia, entirely composed of fragments of siliceous stones, extensive strata of which exist in Egypt and the neighbouring deserts. 2. Striped jasper, which is found in masses, and sometimes forms entire beds, is abundant in Siberia, is met with also in Saxony, in the Hartz, where it reposes on gray wacken, and in the hills in the vicinity of Edinburgh. 3. Porcelain jasper, which has its name from its resemblance to porcelain in fracture and appearance, is supposed to be nothing more than a slaty clay altered by fire, particularly as it is found in places where subterraneous fires have existed, as at Dysart in Scotland, where beds of coal have been kindled accidentally. It is composed of silica 6, alumina 27, magnesia 3, potash 3, iron 2. 4. Common jasper, composed of silica, alumina and iron in variable proportions, is abundant in different parts of the world. 5. Jasper agate, or agate jasper, is met with not unfrequently in amygdaloid rocks. 6. Opal jasper, which is found in Hungary, Siberia, and other places, usually exists in nests in porphyry. A jasper is mentioned by Patrin, which forms the hill on which the fortress of Orskaia is situated, on the left bank of the river Jaik in Siberia, of a pale green and deep red colour, and disposed in inclined beds; and a jasper of an ivory white colour, and penetrated with black dendrites, has been discovered on the most elevated parts of the Altaian mountains.

Heliotrope or *bloodstone*,—is properly enough by some considered as a variety of jasper, and hence called oriental jasper, being brought from the east; but it has been also found in Siberia, Bohemia, and the western islands of Scotland. By others it is supposed to be a calcedony penetrated with green earth.

Chrysoprase—is a mineral composed chiefly of silica, with a small proportion of alumina, lime, iron, and one part of nickel, to the two latter of which its green colour is no doubt owing. It is met with in masses or angular fragments in a mountain composed of serpentine, asbestos, and lithomarga in Upper Silesia.

Plasma—is a mineral which was employed by the ancients for ornamental purposes, and is said by some to have been only found among the ruins of Rome; but according to others, it has been discovered in upper Hungary and Moravia in a mountain of serpentine, where it is accompanied by flint.

Cats-eye,—a mineral brought from Ceylon and the Malabar coast, is singular on account of its chatoyant property, and is composed chiefly of silica, with a small proportion of alumina, lime, and iron; but nothing is known of its natural repository.

Obsidian or *Iceland agate*,—on account of its glassy appearance, and being often found in the neighbourhood of volcanoes, is supposed by some to be a volcanic production. It is, however, it is said, not unfrequent in countries where volcanoes never existed. It is met with in Iceland, Teneriffe, and also Siberia and Hungary, where it is found in insulated masses among detached blocks of granite, gneiss, and decomposed porphyry. Its constituent parts are silica 72, alumina 12, iron and manganese 2, potash and soda 4 to 10, and sometimes a small portion of lime.

Pitch-stone,—which derives its name from its resemblance to pitch, exists in beds and veins, and forms sometimes entire mountains. It is abundant in Saxony, Hungary, and Siberia, and is not uncommon in Scotland, particularly in Arran, where it forms beds, but chiefly veins, traversing the strata in the less elevated parts of that island; and where also it constitutes the basis of porphyry. It is composed of silica 73, alumina 14, lime 1, iron 1, soda 1·75, water 8·5, and a little manganese.

Pearl-stone—is a mineral of a pearly lustre, which forms the basis of a porphyry. It is met with in Hungary in strata, which alternate with argillaceous porphyry, and contain nodules of obsidian, of which indeed it is considered as a variety. The constituent parts are nearly the same as those of obsidian.

Pumice.—This mineral, as it is usually found in the vicinity of volcanoes, has been supposed to be a volcanic production. The Lipari islands are almost entirely composed of it. It is also found in Iceland and Teneriffe, as well as in Hungary and on the banks of the Rhine. The constituent parts approach nearly to those of obsidian and pearl-stone.

Prehnite—is found massive or crystallized in France, where it exists in veins, and not unfrequently in different parts of Scotland; as among the porphyry rocks to the south of Paisley, where it is disposed in nodules and veins; in the neighbourhood of Dumbarton, and sparingly in the rocks round Edinburgh. Prehnite was first discovered at the Cape of Good Hope. It is composed of silica

44 to 50, alumina 20 to 30, lime 18 to 23, iron 5, with a small proportion of water and magnesia.

Zeolite,—according to the arrangement of some mineralogists, is divided into four varieties. 1. Mealy zeolite, which is composed of silica 50, alumina 20, lime 8, and water 22. It is found in Iceland, the Faroe Islands, and in different parts of Scotland, as at Dunbar, and some of the western islands, where it is distributed in veins and cavities of basaltic and amygdaloid rocks. 2. and 3. Fibrous and radiated zeolite, are composed of similar constituent parts in different proportions. 4. Foliated zeolite has a smaller proportion of alumina; and all the three varieties are not unfrequent in amygdaloid rocks, basalts, porphyry, wacken, and green-stone, lining the fissures and cavities in Iceland, Faroe, and in different places of Scotland. *Cubizite*, or cubic zeolite, is found in Skye, Staffa, and the Salisbury rocks near Edinburgh, and is abundant at the Giant's Causeway north of Ireland.

Cross-stone,—which is always crystallized, is found in veins in the Hartz, accompanied by carbonate of lime, in the lead veins at Strontian in Scotland, and in balls of agate at Oberstein, and is composed of silica 49, barytes 18, alumina 16, and water 15.

Natrolite—is remarkable for the large proportion of soda, which amounts to 16, along with silica 48, alumina 24, water 9, and a little iron. The cavities of an amygdaloid rock in Switzerland form its repository.

Lazulite—is supposed to be found in granite in Persia and China, and in Siberia in a vein along with garnets, feldspar, and pyrites. Its constituent parts are silica 46, alumina 14, carbonate of lime 28, sulphate of lime 6, iron 3, and water 2.

Hydrargillite—is found in a tin mine in Cornwall, and also in the cavities and veins of a soft argillaceous schistus; and is remarkable for being composed chiefly of alumina and a large proportion of water. The constituents are alumina 70, lime 1, water 26; and in some specimens a small portion of silica.

Feldspar,—which exists in masses or crystallized, presents several varieties. 1. *Adularia* is either massive or crystallized, and is said to form beds interposed between micaceous schistus and gneiss on St Gothard in Switzerland. It is composed of silica 64, alumina 20, lime 2, potash 14; and according to other analyses a portion of magnesia with iron and barytes. 2. *Lebradore stone* consists of silica 69, alumina 13, sulphate of lime 12, with a small portion of iron and copper; is remarkable for its chatoyant property, and was first brought from Labradore; but has since been found in Siberia, and is supposed to belong to primitive rocks. 3. *Common feldspar* is a very common substance, forming one of the component parts of granite, gneiss, syenite, and porphyry, and approaches to adularia in the nature and proportions of its constituent parts. 4. *Compact feldspar* is found massive, and is not uncommon in Scotland, as in the Grampian mountains, on the Pentland hills, and Salisbury rocks in the vicinity of Edinburgh. 5. *Hollow spar* is a variety which is only found crystallized and imbedded in argillaceous schistus in France and in Cumberland.

3. *Argillaceous Genus.*

Argillaceous earth, alumina, or pure clay, is one of the most universally distributed, and most abundant of all the earths. There are indeed few mineral bodies of whose composition it does not form a part.

Native alumina.—The existence of the pure earth in nature has been doubted. It has been found only in a small quantity, and in the neighbourhood of a large laboratory at Halle in Saxony, which has led to the supposition that it is an artificial production. By one analysis this substance is composed of alumina 45, sulphate of lime 24, water 27, lime and silica 4; but according to others it consists almost entirely of pure alumina.

Porcelain earth—derives its name from its use in the manufacture of porcelain. It is abundant in beds and veins of granite and gneiss, particularly in China and Japan, where it is called *kaolin*. It seems to be formed by the decomposition of granite.

The constituent parts are silica 55 to 71, alumina 15 to 27, lime 2, water 7 to 14, and sometimes a little iron.

Common clay.—Of this there are several varieties, as pipe-clay, which is abundant in most countries, and is usually found in alluvial land; potters clay, also an abundant production in similar situations; slaty clay, or shale, or *till*, abounds in coal countries, and is usually described under the general denomination of one of the coal metals. It is distinguished by impressions of ferns, reeds, or grasses; indurated clay or clay-stone, occupies veins, and sometimes extensive beds, constitutes the basis of porphyries, as in Saxony, and is frequent in Scotland, as on the Pentland hills near Edinburgh. Stourbridge clay seems to belong to this variety.

Adhesive slate,—or polishing slate, forms considerable beds at Menil-Montant near Paris, and is the repository of menilite, formerly mentioned. Is composed of silica 66, alumina 7, magnesia 1·5, lime 1·25, iron 2·5, water 19.

Tripoli—seems rather to be a substance which has undergone some change, as it is found in beds among the strata of coal which have been on fire. It is also found in veins in the neighbourhood of basalts. It is composed of silica 90, alumina 7, iron 3.

Alum-stone,—long known by the name of the *stone of Tolfa*, where it is found, near Rome, forming a mountain traversed by veins of grey quartz. The celebrated Roman alum is obtained from this stone. It is composed of alumina 44, silica 24, sulphurous acid 25, sulphate of potash 3, and water 4; so that it has all the ingredients necessary in the formation of alum in its composition.

Aluminous schistus—is abundant in Saxony, France, England, and Scotland; is disposed in beds among stratiform rocks, and is often traversed by veins of quartz. It contains also pyrites, which contributes to the decomposition of the stone. A variety, which has a shining appearance, is sometimes met with in beds accompanying sandstone, as in a quarry on the east side of Salisbury rocks near Edinburgh.

Bituminous schistus—is peculiar to coal countries, and alternates with slaty clay and coal.

Drawing slate—is a concomitant of aluminous schistus, and forms with it beds which repose on clay slate. It is met with in Italy, France, and Scotland. It is composed of silica 64, alumina 12, carbone 11, iron 3, and water 7.

Whet slate—is found in primitive mountains, forming beds, which are subordinate to clay-slate. It has been discovered in Bohemia, Saxony, and Siberia.

Clay schistus,—or argillaceous schistus, which, according to Kirwan, is composed of silica, alumina, lime, magnesia, and iron, with some bituminous matter, belongs equally to the primitive and stratified rocks, and frequently forms entire mountains. It abounds with metallic ores, which are either in beds or veins, and is sometimes mixed with quartz, mica, hornblende, garnets, pyrites, and cinnabar, as at Idria. Slate, as it is usually called, is abundant in most countries, and is common, particularly in the western parts of Scotland.

Lepidolite.—This mineral, which is but of rare occurrence, has its repository in granite in Moravia and Sweden, and is composed of silica 54, alumina 20 to 38, potash 4 to 18, fluate of lime 0 to 4, with a small portion of iron and manganese.

Mica—is a very common mineral in almost every kind of rock, but particularly in granite, gneiss, and micaceous schistus. Its constituent parts are silica 38 to 50, alumina 28 to 45, lime 1, magnesia 1 to 20, iron 7 to 14.

Pot stone—constitutes entire beds, and is usually accompanied by serpentine, and mixed with chlorite, talc, and asbestus. It is found in Switzerland, Saxony, and Hungary, and in considerable quantity on the banks of Loch Fine, opposite to Inverary in Scotland, hence called *Inverary marble.* Constituent parts, silica 38, magnesia 38, alumina 7, iron 15, with a small portion of lime, and also, it is said, fluoric acid.

Chlorite—presents several varieties, whose constituent parts are nearly the same, differing only in proportion; but from this must be excepted earthy chlorite, which contains a small proportion of common salt. The different varieties of chlorite are not uncommon in many countries, and form beds which repose on clay slate. It is frequently accompanied by garnets, and octahedral magnetic iron. The constituent parts are silica 26 to 41, alumina 6 to 18, magnesia 8 to 39, iron 10 to 40, with a portion of water.

Hornblende,—of which there are several varieties, is of frequent occurrence in many countries. 1. Common hornblende, composed of silica 37, alumina 22, magnesia 16, lime 2, iron 23, is a constituent part of primitive rocks, as in syenite, and is sometimes found in gneiss, primitive limestone, porphyries, and micaceous schistus. It forms entire beds, as in Saxony, and is found in Norway, Hungary, and Britain. 2. Basaltic hornblende, of nearly similar constituent parts, but with a smaller proportion of magnesia, is found crystallized in basalt, wacken, and the lava of Vesuvius. 3. Labradore hornblende, of whose repository nothing is known. 4. Schistose hornblende constitutes extensive beds in primitive mountains, as in Bohemia, Norway, and in the Isle of Skye, and other places of Scotland.

Basalt—is not uncommon in most parts of the globe, and in many places it is very abundant, often exhibiting a regular columnar form, as in several of the Hebrides on the west of Scotland, and particularly in the islands of Eigg and Staffa, and the Giant's Causeway in the north of Ireland. It is also frequently disposed in beds and veins, both of which are very common, particularly on the western coasts of Scotland. Its constituent parts are silica 44 to 50, alumina 16, iron 16 to 25, lime 9, magnesia 2, soda 2 to 4, with a small portion of manganese.

Wacken—sometimes forms beds in the middle of basalt, but is oftener in the form of veins, and constitutes the basis of amygdaloid, whose cavities are filled with green earth, calcareous spar, and other substances. It is common in different countries, and in many places of Scotland.

Phonolite, or *clink-stone*, or *schistose porphyry*, constitutes great part of the island of Lamlash near Arran, and Traprene Law in East Lothian, in both which places it is columnar. It is composed, along with silica, alumina, lime, iron, and a small portion of manganese, of from 6 to 8 parts of soda.

Lava,—which is a volcanic production, is found only in the neighbourhood of volcanoes, and is composed of silica 49, alumina 35, lime 4, and iron 12.

Green earth,—which is found occupying the cavities of amygdaloid rocks, is composed of silica, alumina, iron, water, with a small proportion of lime and magnesia.

Lithomarga—exists in nodules in amygdaloid rocks, or occupies veins and fissures in porphyry, gneiss, and serpentine, in Bohemia, France, and England. Is supposed to contain a large proportion of magnesia.

4. *Magnesian Genus.*

Magnesia, the earth which gives name to this genus, is far less abundant than the earths which characterise the two preceding genera.

Native magnesia.—This is a rare mineral, and has been found in serpentine in Moravia. It is composed of carbonic acid 51, and of magnesia 47.

Bole,—or lemnian earth, from being found in Lemnos, forms nests in basalts, as in Upper Lusatia, and is deposited on indurated clay, as in Silesia.

Sea froth—is disposed in thin beds, in low grounds, in Natolia, Spain, and the Crimea. It is employed in Turkey in the manufacture of the heads of tobacco pipes. It is composed of silica 50, magnesia 17, a small portion of lime, and a large proportion of water.

Fuller's earth—is composed chiefly of silica, alumina, lime, iron, and with but a small proportion of magnesia. It forms beds in Sweden, Saxony, and France, and is disposed between strata of sandstone in Hampshire and other places in England.

Steatites—forms beds and veins in serpentine rocks; as at Portsoy in Scotland. Is sometimes found in metallic veins, and is also imbedded in wacken, as in the Isle of Skye. The constituent parts are silica, magnesia, and alumina, chiefly, with water and a small portion of iron.

Nephrite or *jade*—contains silica 47, magnesia 38, with a small portion of alumina, lime, and iron; is found in Switzerland and other places, and in Iona, one of the Hebrides in Scotland, but always in detached water-worn masses, so that its repository is unknown. Axestone is a variety of Jade, which is employed as a cutting instrument in countries where iron is little known. We are unacquainted with its natural history.

Serpentine—is met with in veins, and sometimes forms entire mountains, as in Saxony, Bohemia, and Siberia; in Cornwall in England, where it contains native copper, and at Portsoy in the north of Scotland. Its constituent parts are silica 45, alumina 18, magnesia 22, iron 3, and water 12.

Schiller-stone—is usually imbedded in serpentine, and is supposed to be that substance crystallized. Its constituent parts are nearly the same as serpentine, excepting that it contains a smaller portion of magnesia, with a larger portion of iron, and some lime. It is found in Moravia, Corsica, and Cornwall.

Talc—presents several varieties, as earthy talc, which exists in veins, cavities, or primitive rocks, as in Bohemia and Inverness-shire in Scotland; common talc, composed of silica 50, magnesia 44, alumina 6, is always found in serpentine rocks, accompanying actynolite and steatites; indurated talc constitutes beds in mountains of argillaceous schistus, gneiss, and serpentine, as in Switzerland, and in the western parts of Scotland.

Asbestus—includes several varieties: 1. Mountain cork, which is called, when in thin plates, *mineral paper*; in thicker plates, *mineral leather*; and in porous or cellular pieces, *mineral flesh*; exists in thin veins in serpentine rocks, or is mixed with quartz and silver ores, as in Saxony; and is found also in the lead veins at Leadhills in Scotland. Its constituent parts are silica, magnesia, and lime, with a small proportion of alumina and iron. 2. Amianthus is also found in serpentine, and has the same constituent parts in variable proportions. It is met with in different parts of the world, as in France, Sweden, Scotland; but the finest specimens are brought from Corsica. Of this substance the ancients manufactured an incombustible cloth for the purpose of wrapping round dead bodies, that the ashes might be preserved unmixed with the wood employed in burning them. 3. Common asbestus is found in similar places with the preceding, but contains neither lime nor alumina. 4. Ligniform asbestus has been discovered in the Tyrol accompanying the ores of lead and zinc.

Cyanite—is a mineral which is often crystallized, and is found in Switzerland mixed with quartz, garnets, and granite, and imbedded in indurated talc. It is also found in France, Siberia, and Scotland, and always in primitive mountains. Its constituent parts are chiefly silica and alumina, with some iron, and a small proportion of lime and magnesia.

Actynolite,—of which there are several varieties, is distributed in beds of serpentine and steatites, or accompanied by quartz, ores of lead, zinc, and iron. Common actynolite is composed of silica, magnesia, lime, with a small proportion of alumina and iron.

Tremolite—presents similar varieties, and is found imbedded in limestone in primitive mountains. It is composed chiefly of silica, lime, and magnesia, with some carbonic acid, and a small proportion of iron.

Smaragdite—was found imbedded in nephrite in the vicinity of Turin; but it has also been discovered among rounded pebbles near the lake of Geneva, and in primitive rocks in Corsica; but the natural history of this mineral is less remarkable than its constituent parts, which are silica 60, alumina 11, lime 13, magnesia 6, oxide of iron 5·5, oxide of chromium 7·5, oxide of copper 1·5.

5. *Calcareous Genus.*

Lime, or calcareous earth, is one of the most abundant and universally distributed of the earths. It exists in all parts of the world, in greater or smaller proportion in all kinds of rocks; and besides, it forms the principal constituent part of immense masses of rock and extensive strata.

Chalk—forms considerable stratified mountains, containing numerous petrifactions, the matter of which is almost always siliceous, as well as flints disposed in regular strata in different countries, particularly in France and England. It is chiefly composed of lime and carbonic acid, sometimes with a mixture of iron and other substances.

Compact limestone—presents two varieties; the first forming extensive stratified mountains, accompanying coal and sandstone, as in Saxony, France, and Britain; and, the second, roe-stone, to which variety the celebrated Portland stone belongs. Foliated limestone is another variety, which includes the different kinds of marbles, and is not uncommon in different parts of the world. Calcareous spar is limestone crystallized in various forms; one of the most remarkable is the rhomboidal double refracting spar. Fibrous limestone is usually found in veins, and being susceptible of a fine polish, was known to the ancients by the name of calcareous alabaster. Satin spar belongs to this variety; as well as calcareous sinter, which is formed in the cavities of mineral veins, and in grottos in limestone rocks; and the singular mineral substance called *flos ferri*, which is of a branched form, and occupies the cavities of veins of sparry iron ore. Peastone is formed by the deposition of calcareous earth on a particle of sand as a nucleus, in the neighbourhood of springs holding that earth in solution. Calcareous tufa is produced by a similar process, the earth being deposited, from waters impregnated with it, on plants or other substances.

Arragonite—is a carbonate of lime, and resembles calcareous spar, excepting in a great degree of hardness, and in its diversity of form, which peculiarities yet remain unexplained. It is found imbedded in gypsum.

Brown spar—usually exists in metallic veins, and is composed of carbonate of lime 50, oxide of iron 22, manganese 28.

Dolomite—is a mineral containing lime, with some alumina and magnesia, which is found abundantly on St Gothard and other primitive mountains.

Bitter spar,—whose constituent parts are carbonate of lime 52, magnesia 45, iron and manganese 3, is found imbedded in chlorite schistus and serpentine, accompanied by asbestus, talc, and tremolite, in the Tyrol and Sweden.

Swine-stone—constitutes entire beds among stratified limestone in France and Sweden. The peculiar odour, from which it has its name, is supposed to be owing to some combination of sulphur and hydrogen.

Marl—exists in great abundance in limestone countries, forming beds, and often immediately under the soil. It is either in an earthy or indurated form. It is composed of carbonate of lime and alumina, and probably also with some portion of silica.

Apatite—is composed of lime and phosphoric acid, is usually crystallized, and is found in tin mines in Germany and Cornwall. Asparagus stone has a similar composition, but has been found only in Spain, and it is said in Norway. Phosphorite is also a phosphate of lime, but contains, besides a small proportion of silica, fluoric, carbonic, and muriatic acids, with some iron. It forms an entire mountain in the province of Estremadura in Spain.

Fluor spar,—which is composed of lime and fluoric acid, with a considerable proportion of water, exists in an earthy, compact, or crystallized form. It is not uncommon in many parts of the world, particularly in the counties of Cornwall and Derby, Durham and Cumberland in England, and in small quantity in Aberdeenshire in Scotland. It is sometimes found in beds, but most commonly in mineral veins.

Gypsum,—which is a compound of lime and sulphuric acid, presents several varieties of form, as earthy, which is a rare production; compact, which is found in Italy, France, and England; foliated and fibrous, which are met with in similar places. Gypsum is found in all kinds of rocks, and forms mountains or beds, which are subordinate to sandstone or limestone. It is very abundant in the neighbourhood of Paris, and in several parts of England; but is rather a rare production in Scotland.

Selenite—is also gypsum, which is frequently crystallized, and is found among beds of gypsum, which alternate with clay and sandstone, in nests in clay, and in the cavities, or on the surface of limestone, which reposes on coal strata, as at Hurlet near Paisley in Scotland.

Cube spar,—which is found in the salt pits at Halle in the Tyrol, where it is called splintery gypsum, is remarkable chiefly on account of its composition, which is sulphate of lime 58, carbonate of lime 11, and muriate of soda 31.

Datholite—is composed of lime 35, silica 36, boracic acid 24, and water 4. It is found in Norway, accompanied sometimes by greenish coloured foliated talc.

6. *Barytic Genus.*

The earth which characterizes this genus is far less abundant than the preceding, and but rarely enters into the composition of minerals which do not strictly belong to it. The genus includes only two species.

Witherite, or *Carbonate of barytes*,—is a rare production; has been found in lead veins, traversing coal strata in Lancashire, where it is accompanied by heavy spar and blende, and is composed of carbonic acid and barytes; or, according to some, with a portion of strontites, alumina, iron, and copper.

Heavy spar, or *Sulphate of barytes*,—is a mineral of more frequent occurrence, and assumes various forms. 1. *Earthy*, which is rare, has been found in Saxony above common heavy spar, and in Derbyshire and Staffordshire. 2. *Compact*, which is usually found in mineral veins, has also its repository in clay-slate, and sometimes in sandstone, as in Northumberland. 3. *Foliated*, not uncommon in mineral veins, and sometimes in beds. 4. *Common*, which is frequently crystallized, is common in metallic veins which traverse primitive mountains, accompanying ores of silver, lead, and copper. 5. *Columnar*, found in Saxony and Derbyshire along with the other varieties. 6. *Prismatic*, whose repository is also in mineral veins. 7. *Bolognian*, which is imbedded in an argillaceous rock near Bologna, and is remarkable for the property of shining in the dark when heated, is composed of silica and alumina, some gypsum, and a small portion of iron, beside the sulphate of barytes. 8. *Granular*, found in Saxony in veins along with galena.

7. *Strontian Genus.*

The earth from which this genus derives its name is very sparingly distributed, the minerals containing it having been discovered only in three or four places. *Strontites*, or the *carbonate*, has been found only at Strontian in Scotland, in a lead vein, traversing a rock of gneiss. The mineral composed of strontites and sulphuric acid, or the *sulphate*, of which there are several varieties, is of more frequent occurrence. The variety of a fibrous structure, or fibrous celestine, has been found in America and France; the foliated and crystallized variety is abundant near Bristol, and it has been found also in Sicily, accompanying fibrous gypsum and native sulphur.

8. *Yttrian Genus.*

The mineral containing the earth which characterizes this genus has been found only at Ytterby in Sweden, and from which the earth derives its name. It contains of Yttria 35 to 59, silica 21 to 25, alumina 4, iron 17·25, a small portion of manganese, with water and carbonic acid.

CLASS. II. *Salts.*

Most of the mineral productions included under this class, although the process of their formation is constantly going on, yet, on account of their solubility in water, by which means they are carried off from their native repositories, exist less abundantly than minerals of a more permanent nature. Saline bodies are usually divided into genera, according to the acid which enters into their composition.

Genus 1.—*Sulphates.*

Native vitriol,—which is a compound of sulphuric acid with iron, and sometimes with copper and zinc, is not uncommon in mountains of clay-slate, which contain metallic ores, particularly those of copper and iron pyrites and blende. The formation of the compound salt is owing to the decomposition of those substances. Native sulphate of iron, or copperas, is common in coal mines, containing iron pyrites.

Native alum—is derived from a similar decomposition, where aluminous stones, and other substances containing iron pyrites, as in the neighbourhood of volcanoes and coal mines, abound.

Mountain butter,—so called from its resemblance to that animal production, and plumose alum, so called from its downy appearance, are found in similar situations, and are impure sulphates of alumina.

Capillary salt, or *sulphate of magnesia,*—is also met with in similar places, and is no doubt the result of similar decompositions. A salt of this kind has been found in Lord Glasgow's coal mines near

Paisley, which are the rich mineral repositories of native vitriol and native alum.

Native Epsom salt,—also a sulphate of magnésia, exists in abundance in the mineral waters at Epsom, is frequently found in a state of efflorescence on limestone, porphyry, and sandstones.

Native glauber salt, or *sulphate of soda*,—is usually found in the neighbourhood of mineral springs which hold common salt in solution; from the decomposition of which, and the combination of its base with sulphuric acid, it is obtained. It is also not unfrequent on the banks of salt lakes, and in a state of efflorescence on sandstone and marl.

Genus 2.—*Nitrates.*

Native nitre, or *nitrate of potash*,—is found near Molfetta in Naples, disposed in small beds, and sometimes, but more rarely in veins, in limestone. It is abundant in the warmer countries of the world, as in Peru and the East Indies, where at certain seasons of the year it is found efflorescent on the surface of the ground.

Genus 3.—*Muriates.*

Rock-salt,—which is not uncommon in many countries of the world, is usually found alternating with beds of clay, accompanying gypsum, sandstone, and lime-stone. Sometimes it is found in considerable beds, but often in detached masses; sometimes also in veins.

Native sal ammoniac—is rather to be considered as a volcanic production, because it is usually found in the cavities of lava, as on Vesuvius and Ætna, in the Lipari islands, and Iceland. It is sometimes found in Britain, in the neighbourhood of coal mines which have been accidentally on fire.

Genus 4.—*Carbonates.*

Native soda—is found on the surface of the soil, or on the borders of lakes, whose waters are carried off during the summer by evaporation. In this way it is collected in Egypt. In Hungary it is found efflorescent on a heathy soil, and in Bohemia on a decomposed gneiss rock, where it is annually collected in considerable quantity.

Genus 5.—*Borates.*

Borax—is a substance composed of soda and boracic acid, which is brought from Persia and Thibet, and is obtained, according to some accounts, from the waters of a lake by evaporation; or according to others, it is ready formed on the borders of the lake, along with common salt.

Genus 6.—*Fluates*.

This genus includes only one species, which, as it is not soluble in water, does not strictly belong to the class of salts.—*Cryolite*, so called from its easy fusibility, is a fluate of soda and alumina. It is composed of soda 32 to 36, alumina 21 to 23·5, fluoric acid and water 40·5 to 47. This singular mineral production is found in Greenland, but of its native repository nothing particular is known.

CLASS. III. *Combustibles*.

1. *Diamond Genus*.

The diamond, which among precious stones holds the first rank, and is usually arranged with them, yet, as it is purely of a combustible nature, may be properly placed at the head of this class of minerals. The diamond is the hardest and most indestructible body in nature; and on account of these remarkable properties, and its splendid and varied play of colours, has been always held in the highest estimation.

Localities of the diamond.—The diamond has never been found without the tropics; and indeed from whatever country it is obtained, whether to the south or north of the equator, it is singular to observe that it is always about the same degree of latitude. Thus the native place of the diamond in the East Indies is about the 18th degree of north latitude; and the diamond mines of Brazil, in the southern hemisphere, are about the same distance from the equator. Of the native repository of the diamond very little is known. It is usually found in a ferruginous soil but whether it be produced on the spot where it is discovered, or transported from the place of its origin, has not been ascertained. It is said, indeed, that it is also found in veins filled with a similar kind of soil; but in no case has it been discovered in the cavities or fissures of any kind of rock, or imbedded in any indurated stony matter, like other crystallized minerals. It is conjectured by Werner, that the diamonds found in the soil at the foot of the mountains Orixa in India, were originally formed in the interior of some kind of trap rocks, from which they were afterwards detached; but I can see no facts connected with the natural history of the diamond which can be adduced in support of this conjecture.

Diamond mines.—1. The diamond mines of Raolconda, five days journey from Golconda, have been discovered at least 200 years. This mine, in the time of Tavernier, is described as being in a sandy and rocky soil, which he compares to the vicinity of Fountainbleau in France. The veins in these rocks, not wider than a finger's breadth, are filled with earth and sand, which are dug out by means of long hooked iron instruments, and being collected in sufficient quantities, are carefully washed to separate the diamonds. Above a hundred years ago, twenty mines, or places where diamonds are found, were known in the kingdom of Golconda; and about fifteen in that of Visapour. These mines, it is said, are now abandoned.

2. *Mine of Coulour.*—This mine is seven days journey to the east of Golconda, and in a plain of a league and a half in extent, bounded on one side by a river, and by a chain of high mountains in the form of a crescent on the other. The soil of this plain is raised to the depth of several feet, and it is said, the nearer they dig to the mountains, the larger are the diamonds; but when they reach a certain elevation, no diamonds are found. The famous diamond of the great Mogul was found here. The diamonds of this mine, it is farther added, are not very clear, being usually tinged with the quality of the soil; for when the soil is marshy, the diamonds deposited in it have a blackish tinge; red, when the soil is red, and green or yellow, if the soil be of those colours. Sixty thousand persons are here employed in searching for diamonds.

3. *Mine of Soumelpour.*—This is the name of a considerable town situated on the river Goual, which discharges its waters into the Ganges. It

is in the sand of this river that the diamonds are found, and particularly in those places where the sand is mixed with pyrites; which circumstance, according to Patrin *, indicates that the materials of this soil are derived from rocks of primitive schistus. From this river the diamond points or sparks, called *natural sparks*, are obtained. The search for the diamonds in this river commences about the month of December or January, after the great rains. Eight or ten thousand persons of all ages and sexes, from Soumelpour and the neighbouring villages, are employed in the different operations. The most experienced search and examine the sand of the river, proceeding from Soumelpour as high up as the mountain from whence it issues. The river being at this time very low, the sand in which diamonds are likely to be found, is taken up by damming the particular place round with stones, earth, and fascines, and throwing out the water: they dig two feet deep, and carry off the sand thus raised, into a place walled round on the bank of the river. In this place the whole is washed and carefully searched.

4. *Mines of Borneo*, &c.—Very fine diamonds have been brought to Batavia by stealth from the river Succudan in Borneo; but as strangers are prohibited from having access to it, nothing is

* Hist. Nat. des Mineraux, i. 229.

known of its history. It was formerly imagined that the diamonds from Borneo were of a softer nature than those of other mines; but it does not appear from experience that they are in any respect inferior. The diamond is also found to be a natural production of the kingdoms of Pegu and Siam, and also about the eighteenth degree of north latitude.

5. *Mine of Serro-Do-Frio in Brazil.*—The diamonds of the Indian continent are in general of a larger size, and of a finer water than those of Brazil; but the latter, though smaller, are more abundant. The American mine is situated to the north of Villa Rica, in the eighteenth degree of south latitude. The whole country which produces diamonds, abounds with iron ores, and the stratum immediately under the vegetable soil contains diamonds disseminated in it, and attached to a gangue or matrix more or less of a ferruginous nature. The diamonds of this country are never found in veins. This mine was discovered in 1728; and the search for diamonds was at first so successful, that the Portuguese fleet which arrived from Rio de Janeiro in 1730, brought no less than 1146 ounces of diamonds. The price immediately fell, in consequence of this unusual quantity being introduced into the market; and to prevent the recurrence of the same thing, the Portuguese government determined to limit the number of men employed in the mines.

Remarkable diamonds.—Before the revolution in France, several fine diamonds belonged to the crown of that kingdom, in particular one, called the Sancy of 55 carats weight, which cost 25,000 guineas, and is said to be worth twice that sum. Another, called the *Pitt* or *Regent*, weighing 136 carats, which is said to be one of the most perfect diamonds known, and to be worth above 208,000 guineas. The latter diamond, Patrin says, is believed to be at Berlin, but it has probably returned to France with other spoils.

A very fine diamond belonging to the crown of Portugal, weighs 215 carats, and is valued at 369,000 guineas. The diamond of the Great Mogul weighs 279 carats, and is valued at 380,000 guineas. But this is far inferior to the celebrated diamond which adorns the sceptre of the Russian monarchs; it weighs 779 carats, and cost little more than 135,417 guineas, but is valued at the extraordinary sum of L.4,854,728 Sterling. This diamond was originally one of the eyes of a Malabarian idol, from which it was stolen by a French grenadier. It was bought for 20,000 rupees by a ship captain, who sold it to a Jew for L.17,000 or L.18,000 Sterling. A Greek merchant afterwards offered it to sale at Amsterdam, and it was afterwards purchased in 1772 by the favourite prince Orloff for the empress of Russia. This celebrated diamond is of the size of a pigeon's egg, and of a flattened oval form. But the diamonds now noticed are far exceeded by one belonging to the crown of Portugal, which was found in Brazil. This diamond weighs 1680 carats; and although it is uncut, it is valued, according to Romé de Lisle, at L.224,000,000 Sterling, or according to a more moderate estimation, at about L,5,500,000 Sterling. But it is conjectured by some, that this pretended diamond is only a white topaz.

Constituent principles of the diamond.—Mr Boyle, it is said, was the first who, about the year 1673, subjected the diamond to the action of heat, and he found that it exhaled copious acrid vapours. In 1694, in presence of Cosmo III. grand duke of Tuscany, diamonds were exposed to the heat of the powerful burning glass of Tschirnhausen, and at the end of thirty seconds a diamond of twenty grains lost its transparency, separated into small pieces, and was at last totally dissipated. Newton observed, that the refractive power of combustible bodies was considerably higher than in the ratio of their density; and hence, according to this general law, he inferred that the diamond, possessing so extraordinary a refractive power, must be of a combustible nature; and he supposed it to be a coagulated unctuous substance. This sagacious conjecture, which was announced to the Royal Society in 1675, has been since completely verified. But it is a curious circumstance, that seventy years before the publication of Newton's Optics, in which his conjecture is stated, Boetius de Boodt, in his history of stones, seems to have been perfectly satisfied, from an experiment which he describes, of the combustible nature of the diamond. He speaks of the matter of which it is composed being *combustible and sulphureous, and oily and inflammable**.

The real nature of the diamond has been fully developed by the researches of modern chemistry. The fact of its combustibility is completely established by the experiments of Macquer and Bergman. Lavoisier showed that the product of the combustion of the diamond is carbonic acid; and Tennant and Guyton concluded from their experiments that the diamond is pure carbone crystallized. But Biot, by an ingenious method of proceeding in the discovery of the elementary principles of this gem, has arrived at a different conclusion. Having remarked that he could calculate, with sufficient precision, the refractive power of a body from that of its constituent parts, he measured the refraction of carbonic acid, as well as that of oxygen, one of its constituents, and hence deduced the refraction of carbone, the other constituent, which he found to be in a very low degree; and from this he concluded, that the diamond which possesses a great refractive power, is not merely composed of pure carbone, according to the ge-

* Gem. et Lapid. Hist. Hanoviæ 1609, 4to. lib. II. cap. I.

neral opinion; but that it must be combined with a large proportion of hydrogen, not less than one-fourth of its weight, as estimated by Biot, to render it capable of that degree of refraction which it exhibits. Hence, according to this investigation, the diamond is a combustible body, composed of carbone and hydrogen.

GENUS 2.—*Sulphur.*

Sulphur is widely distributed in the mineral kingdom. In certain situations it exists in great abundance in a detached form, but most frequently in combination with other substances, and in particular with many of the metals. In the uncombined state it is usually crystallized, and is divided into two varieties, common and volcanic native sulphur.

1. *Common native sulphur*—is most commonly found in that class of rocks which are connected with gypsum and salt, such as marl and argillaceous schistus; and it is usually in the latter, which repose on gypsum, or alternate with it, that the sulphur is disposed, either in small irregular masses, in crystals, or in veins, traversing the rocks in all directions; and sometimes also in considerable beds. It appears then to be a pretty general fact in geology, from which there are few exceptions, that gypsum, marl, rock-salt, and sulphur, are associated together in the same distribution of the strata.

Common native sulphur is of frequent occurrence in many parts of the world. It is abundant in the valleys of Noto and Mazzara in Sicily, where it is disposed in horizontal strata of considerable thickness, which afford large and well defined crystals. This sulphur, according to the observation of Dolomieu, is mixed with fine crystals of sulphate of strontites; so that although it exists in the vicinity of Ætna, he thinks it has no connection with the volcano of that mountain, and is therefore not to be considered as a volcanic production; for it is disposed in a class of rocks which have not been subjected to the action of the volcano. The same variety of sulphur is also found in other parts of Italy, as well as in many other places of the world, and always distributed in marl, limestone, or gypsum.

This variety of sulphur exists also in primitive rocks, where it is disseminated in veins, traversing those rocks. This, however, is a rare occurrence, and the sulphur is in small quantity. Humboldt relates as a singular fact, the discovery of sulphur in a bed of quartz approaching to hornstone, which traverses a primitive mountain of micaceous schistus. This fact he observed in the great sulphur mountain of Quito. He mentions also having discovered two other repositories of sulphur in primitive porphyry in the same province.

Sulphur is sometimes found in the state of powder, in flints, and particularly near Poligny in the department of Jura. These flints are very much corroded, and contain in their interior sulphur, mixed with siliceous earth.

2. *Native volcanic sulphur.*—Volcanic regions are the principal sources from which the sulphur of commerce is chiefly derived. In these regions it is found sometimes crystallized in confused groups, but it usually exists in thin layers, in masses, and rounded pieces, or in a stalactitical or cellular form. All volcanoes, in a state of activity, afford sulphur, in greater or less proportion, as one of their products; but the volcanic countries which yield it in greatest abundance, are Solfatara near Puzzuoli, in the Neapolitan territory, which is regarded as the crater of an ancient volcano, and has furnished sulphur from the time of Pliny; the sulphur mines in the Roman states, some of which are of volcanic origin, and others, as those of the duchy of Urbino, seem to be doubtful; those of Iceland, situated in the eastern and western parts of that island, where the sulphur is found in great abundance almost on the surface; those in the island of Guadaloupe, in a volcanic mountain, which still continues to burn; and those of Quito in South America, from which a great quantity of very pure sulphur is obtained.

3. *Bituminous Genus.*

This genus includes the five following species petroleum or mineral oil, mineral pitch, amber, mellite or honeystone, and coal.

1. *Petroleum*—is a bituminous substance, of which the constituent parts are carbone, hydrogen, and a small proportion of oxygen. It is usually found in the vicinity of coal, and floats on the surface of water which flows from coal strata. There is a well of this kind at St Catharine's near Libberton, to the south of Edinburgh. Similar springs have been observed in Lancashire. Naphtha is considered only as a purer kind of mineral oil, and is abundant in different parts of Persia, on the shores of the Caspian Sea, and in Calabria, Sicily, and America. A spring of Naphtha, of a yellow colour, which burns easily, and leaves little residue, was discovered in 1802 in the state of Parma in Italy, and yielded such a quantity as to be sufficient to illuminate the streets of Genoa.

2. *Mineral pitch*—includes several varieties; 1. elastic mineral pitch, or mineral caoutchouc, which was discovered in the mine of Odin in Derbyshire, accompanied by galena, calcareous spar, heavy spar, fluor spar, and blende, and which has the property of obliterating the marks of black lead on paper, like vegetable elastic gum; 2. earthy mineral pitch, containing a greater proportion of earthy matter, and found in Switzerland; and, 3. slaggy mineral pitch, asphaltum, or Jews pitch, which is sometimes connected with coal and limestone strata, and sometimes with mineral veins.

But it is chiefly found floating on the surface of the lake Asphaltum in Judea, where it is collected as an object of commerce; and still more abundantly in the island of Trinidad, where there is a pitch lake of four miles in circumference. But it appears from specimens examined by Mr Hatchett, that the substance supposed to be mineral pitch, is only a porous stone of an argillaceous nature, impregnated with that matter.

3. *Amber*,—of which there are two varieties, white and yellow, is composed of a large proportion of oil, and a peculiar acid, the succinic, which is obtained from it by distillation. Of the origin of this substance nothing except what is founded on conjecture is known. Amber is usually found on the shores of the ocean, and chiefly on the shores of the Baltic; sometimes also in Sweden, France, Italy, and the east coast of England, and sometimes in the vicinity of bituminous wood.

4. *Mellite* or *honey-stone*,—is a rare mineral production, having been found hitherto only in Switzerland, accompanied by mineral pitch, and at Artern in Thuringia, adhering to bituminous wood. This mineral is composed of alumina 16, mellitic acid 46, and water 38.

5. *Coal*—has been divided by some into three different species, brown coal, black coal, and coal blende, or blind coal; each species including several varieties. The first, brown coal, includes common brown coal, bituminous wood, and earthy

coal. The second, black coal, contains six varieties, pitch, columnar, slaty, cannel, foliated, and coarse coal. The third species, coal blende, is subdivided into two varieties, conchoidal and slaty coal blende. But according to the arrangement adopted by Brongniart, the different kinds of coal are subdivided into three varieties; compact coal, fat coal, and dry coal.

1. *Compact coal.*—This includes the variety of coal known by the name of cannel and Kilkenny coal. This coal has much the appearance of jet, burns with a bright flame, but does not give out any pungent or disagreeable odour. It may be easily cut into different shapes, and is susceptible of a fine polish. It is not uncommon in different parts of the world, accompanying the other varieties of coal, as at Whitehaven and Wigan in Lancashire, in England; in the neighbourhood of Edinburgh, and in Ayrshire in Scotland; and at Kilkenny in Ireland.

2. *Fat coal.*—This includes slaty coal, which is the prevailing coal in Britain, as at Newcastle and Whitehaven in England, and in the coal country both in the east and west of Scotland. It includes also the foliated variety of coal. This coal is light, friable, very combustible, burning with a whitish flame; swells up, and seems to enter into a kind of fusion, while it runs together, or cakes as it is called. It leaves little residue, and yields by distillation, bitumen and ammonia.

3. *Dry coal.*—Under this is included pitch coal, and coal blende or blind coal. The dry coal, or blind coal, is more solid than the first, is of a lighter black colour, approaching to iron gray; burns less easily, and with scarcely any flame, without swelling up or adhering together, and leaves more residue. It affords by distillation neither ammonia nor bitumen, but sulphurous acid only. It is said that all the coal found along with compact limestone belongs to this variety, such as that in the neighbourhood of Marseilles, of Aix, and Toulon in France. It is said also that the schistus which covers this variety of coal, contains rather impressions of ferns than of grasses. This coal is also not uncommon in different parts of Scotland, where it is accompanied seemingly with the usual coal metals, as in the coal field to the south of Kilmarnock.

Lignite.—This forms a species of the same author, and includes the varieties of coal which are not comprehended in any of the three preceding and of this species he has formed four varieties.

1. The first is jet, a hard, solid, compact substance, which is susceptible of a fine polish. This is the pitch coal of the first arrangement. It is found in many coal countries, as in different parts of France, in Germany, Spain, and also in Iceland.

2. *Friable lignite.*—This includes moor coal, and is very common in the south of France, where

it is met with in masses of sand, which are frequently deposited in valleys of limestone. It exists also, but more rarely, in clay marl.

3. *Fibrous lignite.*—This variety exhibits the form and texture of wood, and is sometimes found in very large masses, as in the neighbourhood of Paris, and near Vitry on the banks of the Seine. It is in considerable abundance at Bovey near Exeter in England; sometimes in the coal fields round Edinburgh; and in small quantity in the island of Skye in Scotland. It is not uncommon in Iceland, where it is known by the name of *suturbrand.* The trunks of trees, of which this suturbrand of Iceland is composed, are very distinct in their texture, and seem only to have been compressed.

4. *Earthy Lignite.*—This is the earthy coal, or earthy bituminous wood, known in commerce by the name of umber or Cologne earth, which burns very easily, but usually gives out a disagreeable odour. It is sometimes found in the vicinity of mines of common coal, but most frequently in alluvial soil.

Genus 4.—*Graphite.*

Graphite or black lead, or plumbago, is composed of about 90 parts of carbone and 10 of iron, when it is very pure. This, however, is but seldom the case, for it is frequently contaminated with earthy matters, as silica and alumina. A specimen analysed by Vauquelin, afforded 23 of carbone, and 2 of iron only, with no less than 38 of silica, and 37 of alumina. Two varieties of this mineral have been described. The one is of a foliated structure, and the other is granular or compact.

Graphite, in a state of much purity, is comparatively a rare mineral production; and indeed the impurer varieties are not of very frequent occurrence. It is met with in different places in France, as in the mountain of Lubacco, where it is disposed in small veins in granite, and in the valley of Pellis, in the department of the Po, also in veins in a similar rock; in the mountains of Arragon in Spain; in Bavaria; and near Arendal in Norway.

But the most celebrated mine of graphite is at Borrowdale near Keswick in Cumberland. The mountains in the neighbourhood are composed of blue argillaceous schistus, and contain some veins of copper and lead. The mine of graphite is situated in the south side of the mountain, which is of a considerable height, and it is disposed in a bed lying between the strata of schistus, which are traversed by quartz veins. The bed is said to be from eight to nine feet thick, and it is found in masses of various sizes, and of very different qualities; sometimes being too hard, as when it is mixed with earthy matters, or too soft and friable for being manufactured into pencils. This mine is only opened once every three or four years, the quantity thus obtained being found sufficient for the demand.

The only other mine of graphite in Britain is in Ayrshire in Scotland. This mine is situated in the upper part of the county, at a place called Craigman, in the parish of New Cumnock, not far from the source of the river Nith, and at the extreme boundary of the coal field. The rocks which accompany the graphite, however, are somewhat different from the coal metals. The bituminous shale and aluminous schistus, which are the usual concomitants of coal, are wanting. Above and below the stratum in which the graphite is distributed, there are considerable beds of grayish sandstone. The intermediate strata are whinstone or greenstone, which are in immediate contact both above and below with the graphite. A bed of argillaceous, or rather siliceous schistus from its hardness, not less than eight or ten feet thick, reposes on the upper stratum of whinstone. The same kind of schistus, possessing an equal degree of hardness, and having a smooth conchoidal fracture, is interposed between the masses of graphite in the bed in which the latter substance is distributed. The schistus indeed, which is of a light bluish colour, approaches, in its degree of hardness, to whinstone, and is supposed by some, who speculate on the formation of the graphite, to have been projected in a state of fusion into a bed of coal, and to have thus occasioned a partial calcination, by which the coal, being deprived of its bitumen, is converted into graphite or black lead.

The mine which has been opened for the extraction of the black lead enters at the side of the hill, and the space excavated by digging out the graphite, and the interposed rock, is from three to four feet in thickness. The graphite, it has been observed, is distributed in the bed in which it lies in irregular masses, and the spaces unoccupied by that mineral are filled with a hard siliceous schistus, and in some places with whinstone.

In a section of the rocks which is open to the day, a little to the westward of the mine, the graphite exhibits a columnar form, somewhat resembling a range of basaltic pillars in miniature. The columns are pentagonal, about one-half inch in diameter, from three to five inches long, and slightly curved. In no part of the mine, the whole excavation of which I examined particularly, could I discover any of the black lead of this columnar form, which it was natural to expect should have been the case, if this columnar, or crystallized form as it is called, be owing, according to the theory above alluded to, to the fused stony matter being brought into contact with a mass of coal. A substance, in appearance similar to this columnar graphite, is found in contact with a whin dyke, which traverses a coal field near Old Cum nock; but according to Mr Taylor, who describes it, the columns lie in a horizontal position, and at right angles to the side of the dyke. In the section of the strata accompanying the graphite, they are nearly perpendicular. The coal field of Sanquhar also furnishes a columnar coal of similar properties, and having nearly the same relative position.

CLASS IV. *Metallic Ores.*

Metallic ores form the last class or great division of simple minerals. According to the usual mode of arrangement, the ores of each metal constitute a separate genus, and are subdivided into species, the characters of which are derived from the external appearance, or physical properties, and the chemical analysis or peculiar composition. As a pretty full detail of the natural history of metallic ores is to be given in a future chapter, the short description of them, considered as simple minerals, which, agreeable to the plan pursued in the other classes, should have been here introduced, may properly enough, and to save repetition, be reserved to that chapter. I shall therefore now proceed to the next Section, which treats of compound minerals.

SECT. II.

OF COMPOUND MINERALS OR AGGREGATES.

Compound minerals or aggregates are composed of two or more simple minerals united together in the same mass. Thus, in the example formerly noticed, quartz, feldspar, and mica, are simple minerals; but when they are combined together in one mass, they form a compound mineral or aggregate, distinguished by the name of *granite*; and again, feldspar or quartz, disseminated in any simple mineral as a basis, constitutes a numerous class of compound rocks, known by the name of *porphyries*.

The great masses of rock which appear on the surface of the earth are composed partly of simple minerals, as argillaceous schistus, limestone, and basalt, which have been already described in the preceding section, and partly of compound minerals, as granite and porphyry. But when simple minerals are considered as constituting extensive masses, they are also brought under the denomination of compounds or aggregates, and are arranged in the same class.

Rocks or compound minerals have been divided into two great classes, which are characterized by names expressive of the order or supposed periods of their formation. The first class, or the primitive rocks, contain no vegetable or animal remains; from which it is inferred that they were formed previous to the existence of organized beings, the remains of which are discovered in the second class, or the secondary rocks. Proceeding on a still more hypothetical principle, Werner and his followers arrange compound minerals into four classes, viz. primitive, transition, stratified or floetz, and alluvial. By the class of transition rocks is meant those which are supposed to have been formed while the earth was passing from the uninhabited state, or about the time that animals and vegetables first existed; because in this class of rocks petrifactions of the lower orders of organized beings only are observed. But as the first method of arrangement is far more simple, and less connected with theory, while at the same time it is equally accurate and perspicuous, I shall, with Mr Kirwan, divide the whole into primitive and secondary rocks.

CLASS I. *Primitive Rocks.*

The rocks which are included in this class are, 1. granite, 2. gneiss, 3. micaceous schistus, 4. argillaceous schistus, 5. limestone, 6. porphyry,

7. trap, 8. serpentine, 9. syenite, 10. topaz rock, 11. quartz, 12. siliceous schistus, 13. gypsum.

1. *Granite.*

The component parts of granite are feldspar, quartz, and mica, of which the two first frequently exhibit a crystallized form. The proportions of the constituent parts of granite are extremely variable, but in general the feldspar is most abundant; sometimes the proportion of quartz is very small, and often the mica is scarcely perceptible. Sometimes too the ingredients of granite are very unequally distributed, and in particular the feldspar, which is disposed in large masses, as is sometimes observed in the granite of the island of Arran, as well as in that from the island of Mull. In the latter, the crystals of feldspar are from one to several inches in diameter. In some specimens of granite from Arran, the mica assumes a crystallized form, the breadth of the crystals not exceeding the thirtieth part of an inch. The quartz of granite is generally of a grayish colour; the feldspar is whitish, gray, or reddish, and the mica is sometimes black, and sometimes white. Beside the three principal ingredients now mentioned, some varieties of granite contain also schorl, hornblende, and garnets.

Granite of Scotland.—Although in this country granite is not a very abundant rock, yet it affords several varieties. The granite of Goatfield in the island of Arran, sometimes contains the feldspar and quartz pretty equally distributed, but sometimes the former is in considerable masses. In this granite the proportion of mica is small, and sometimes is regularly crystallized, as has been already noticed. In the cavities of this granite the feldspar is often regularly crystallized, and sometimes accompanied with fine crystals of a smoky colour of different shades, known by the name of Arran stones. These are rock crystal, coloured probably with iron or manganese, and are similar to what are called Cairngorum stones, which are found in the north of Scotland. Arran affords another variety of granite, in which the feldspar is the most abundant ingredient, and is of a reddish colour. This, however, may be owing to some change in its constituent parts, as it exhibits the appearance of decomposition. In this variety the feldspar, but particularly the quartz, is crystallized in the small cavities, which are numerous, even in moderate sized specimens. The mica, which is in very small proportion, is of a black colour.

In the granite, on the west side of the island of Mull, the feldspar, as already noticed, is by far the most abundant ingredient. It is of a fine pale flesh-red colour, and some of the crystals are of a very large size. The proportion of mica is very small.

A granite from some parts of the counties of Ross and Inverness, is remarkable for having the mica in greatest abundance; the quartz is in very small proportion, and the feldspar is frequently studded with garnets.

In the granite found at Aberdeen and its vicinity, which from its appearance comes under the denomination of *gray granite*, and from the grains of the ingredients of which it is composed, being of small size, it is called small grained granite, the feldspar and quartz are in the greatest proportion. The quantity of mica is small, and its place is sometimes occupied by small specks of hornblende or schorl.

Granite from Wexford in Ireland.—The prevailing ingredients in this granite are feldspar and mica; the feldspar is of a dull white colour; the mica is of a shining silvery white, and the quartz, which is in the smallest proportion, is gray. In this granite the ingredients are pretty uniformly mixed.

Egyptian granite.—This granite is composed of whitish quartz, of large irregular crystals of red feldspar, and, according to some, of a small proportion of black mica. The feldspar is by far the most abundant ingredient, and the mica is in smallest quantity; but this latter is said by some to be hornblende, which I perceive to be the case in a specimen of Egyptian granite in my possession: and farther, I observe in the same specimen, that the hornblende is always connected with the quartz; none of it is imbedded in the crystals of feldspar. From the circumstance of hornblende being substituted for mica in the Egyptian granite, this stone is by some brought under the denomination of syenite, a name derived from the ancient city of Syene, near which the rocks yielding this granite are situated. Of this stone the numerous obelisks and columns, which still exist in Egypt, were formed, and in particular the celebrated column above ninety feet of elevation, known by the name of Pompey's pillar.

Granite of Ingria.—A beautiful red granite is found in rounded blocks in the neighbourhood of Petersburgh and other parts of Russia, which presents a remarkable peculiarity. The feldspar is of a globular form, from one half inch to two inches in diameter; so that when this granite is polished, the feldspar exhibits shining spots of a round or oval figure, which gives it the appearance of being studded with precious stones. The royal summer garden at Petersburgh is decorated with a superb colonade of this granite. The columns, which are sixty in number, are each composed of a single piece twenty feet long and three feet in diameter. Many of the public buildings are constructed of the same granite. An immense mass of the same stone, which was formerly thirty-two feet long, twenty-one broad, and seventeen high, forms the pedestal for the statue of Peter the Great*.

Corsican granite.—One of the most remarkable granites has been found in detached masses in the island of Corsica. The ground of this beautiful stone is a gray granite, composed of quartz, feldspar, black schorl, and a little yellowish mica. This ground is studded with equal round spots, from one and one-half inch to two inches in diameter. These spots are formed of concentric zones; the external zone is white and opaque, of two or three lines in breadth, and composed of quartz, mixed with feldspar, somewhat radiated, and converging towards the centre of the spot. The next zone is about one and one-half line in breadth, of a black colour, and composed of thin plates of hornblende or schorl. To this black zone succeeds another of white semi-transparent quartz, about four or five lines broad; but it is divided by two or three black zones, not thicker than a thread. All the zones now described are perfectly parallel to each other. The central part of the spot is from seven to eight lines in breadth, and is composed of two very irregular zones, of black and white matter, and in the centre there is a small mass, in which the black is predominant†.

Graphic granite.—This variety of granite is not of very frequent occurrence. It has been found

* Patrin, i. 95.

† Ibid. i. 97.

by Patrin in Siberia, by Besson in Corsica, and was first discovered by Dr Hutton near Portsoy in the north of Scotland. The graphic granite of Siberia, as it is described by Patrin, is a rock whose ground is a whitish or reddish yellow feldspar, with a foliated texture and shining aspect; and in this feldspar are imbedded crystals of quartz, or rather carcases of crystals, from an inch to one and one-half inch long, and several lines in diameter. These crystals, it must be admitted, have something of the appearance here described. It is not, however, easy to conceive how the external laminæ of the crystal should exist, unless it can be supposed that it was formed on a nucleus; and this nucleus being composed of less durable materials than the external covering, the latter has remained after the decomposition or destruction of the former, and has been surrounded by the feldspar: but of this mode of formation there seems to be no proof whatever. These crystals, it is observed, are often arranged in the mass of feldspar, parallel to each other for the space of several square inches, and the interposed space between each crystal is about equal to its diameter. Patrin observes, that the graphic granite of Europe is different from the Siberian, in having the feldspar crystallized in rhomboidal prisms, while the intervening space is filled with amorphous quartzose matter. This is the case with some varieties from Portsoy; but there are others which correspond exactly with that from Siberia, described and figured by that naturalist. The name graphic granite is derived from some resemblance to Hebrew or Arabic, and sometimes to musical characters, which the sections of the quartz crystals exhibit.

Granite mountains usually present lofty insulated cliffs or peaks with rugged and precipitous sides; and although they afford many metallic substances, yet they are found to be less rich in ores than some other rocks. Iron and tin are the most abundant.

2. *Gneiss.*

The same ingredients as those of granite enter into the composition of gneiss; but in gneiss the different ingredients of which it is composed are not indiscriminately distributed through the whole mass as in granite, but each is arranged separately, forming a distinct lamina or plate. The mica is in general the predominant part of this compound rock; and to this its slaty or foliated structure is ascribed. The stratification of gneiss is distinct and well marked.

Mountains composed of gneiss have gentle declivities and rounded summits, and they are generally rich in metallic ores, affording some in great abundance.

3. *Micaceous Schistus.*

In this compound rock the feldspar is generally wanting. It is chiefly composed of quartz and mica; is of a slaty structure, and always stratified. Micaceous schistus contains many foreign minerals; garnets are often imbedded in it in great abundance, and sometimes crystals of tourmaline. It contains also beds of other rocks, as limestone, serpentine, and gypsum, and it is rich in metallic ores, which are distributed in beds or veins.

4. *Argillaceous Schistus.*

The ingredients which enter into the composition of this rock have been already described. Its structure is slaty, and it is regularly stratified. When it comes in contact with micaceous schistus, it seems to be composed nearly of the same ingredients. The quartz and mica appear quite distinct. The garnet, tourmaline, hornblende, and schorl, are not uncommon in this rock. It contains also various metallic ores, and in particular the sulphurated ores, as the pyrites of iron, copper, and arsenic, which are either disposed in beds or veins.

5. *Limestone.*

Limestone is not peculiar to the primitive rocks; it is of very frequent occurrence in the secondary class, and it is said that it is distinctly characterised to admit of this division; the primitive limestone having a crystalline texture, and some degree of transparency, while the texture of the secondary is earthy, and at the same time completely opaque.

Primitive limestone sometimes appears distinctly stratified; is commonly disposed in beds, and rarely forms entire mountains. It contains different minerals, as garnet, hornblende, serpentine, and various metallic ores, as those of lead, iron, blende, and pyrites, distributed in beds or veins.

6. *Trap.*

The word trap, which in the Swedish language, from which it is derived, signifies a stair, was originally applied to those rocks which exhibit something of the appearance of the steps of a stair. The term was afterwards extended to other rocks, and became at last of very indefinite signification. The term is now limited to those rocks which are chiefly characterised by the hornblende forming part of their composition.

Trap rocks are not limited to the primitive class;

they appear also in the secondary. In the primitive trap, the hornblende is almost pure, but in the secondary traps it gradually degenerates into a ferruginous and blackish indurated clay. Primitive trap is almost entirely composed of hornblende; it sometimes, however, contains an admixture of feldspar, and more rarely mica, with some other substances, chiefly pyrites. Primitive trap includes several varieties of rock; these are, common hornblende, slaty hornblende, primitive greenstone, and schistose greenstone. The two first of these have been already described.

Primitive greenstone.—This rock is composed of hornblende and feldspar, and it is subdivided into several varieties, according as the texture is more or less granular or compact. 1. Common greenstone, in which the hornblende and feldspar are intimately aggregated, having a granular texture, and in which the hornblende is in the greatest proportion. 2. Porphyritic greenstone, in which the grains are smaller, and which contains also crystals of feldspar, so that the texture is both granular and porphyritic. 3. Greenstone porphyry, in which the particles of hornblende and feldspar are so fine, that they are scarcely distinguishable, and the texture becomes quite porphyritic. 4. Green porphyry of the ancients is composed of the same ingredients, but so intimately mixed that it appears to be a simple rock; always contains crystals of feldspar; the ground is usually of a deep green, and the crystals of feldspar, which are sometimes arranged cruciformly, are of a lighter green, inclining to white.

Schistose greenstone.—This rock is composed of compact feldspar, hornblende, a little mica, and more rarely some grains of quartz. The hornblende and feldspar are nearly in the same proportion, and the structure, as the name imports, is slaty. This rock is often traversed by metallic veins.

7. *Serpentine.*

Serpentine is a rock essentially simple, and has been already described. It is, however, sometimes accidentally mixed with talc, asbestus, amianthus, steatites, mica, garnets, which give it the appearance of a compound rock. Serpentine is not regularly stratified, and rarely contains any foreign beds. Excepting native copper and magnetic iron, it is in general destitute of metallic substances. Serpentine is disposed in beds, in gneiss, and micaceous schistus, and alternates with limestone.

8. *Porphyry.*

The term porphyry is employed to denote a compound rock, in the principal mass of which are imbedded grains or separate crystals of some other substance. This peculiarity of structure is common to a great many rocks, which derive their specific names from the ground or basis of which the mass is chiefly composed. Thus, in *hornstone porphyry*, crystals of quartz or feldspar are interspersed in a basis of hornstone; 2. in feldspar porphyry, the ground or basis is feldspar; 3. syenite porphyry is different from the former, in having a mixture of hornblende porphyry with the feldspar; 4. pitchstone porphyry has a ground of pitchstone, which is red or green, and sometimes brown or black; 5. argillaceous porphyry, in which the basis is an indurated clay, containing interspersed crystals of feldspar or quartz.

Porphyry is not stratified, and contains no foreign beds; and although it is less rich in metallic ores than some other rocks, yet valuable veins have been discovered in argillaceous porphyry.

9. *Syenite.*

Syenite is a rock essentially composed of grains of feldspar and hornblende, intimately aggregated. The feldspar is usually the prevailing ingredient; and when the feldspar is compact, and contains interspersed in it crystals of feldspar and quartz, the rock assumes a porphyritic structure, and hence is called *syenite porphyry.* Grains of quartz and mica, but in small proportion, are sometimes accidentally mixed in this rock. The texture of syenite is granular, and rarely becomes slaty.

Syenite is not usually stratified, and does not contain any foreign beds; but it is sometimes traversed by metallic veins. This rock usually reposes on porphyry.

10. *Topaz Rock.*

This rock is composed of quartz, schorl, topaz, and lithomarga; the first three substances being disposed in thin beds or layers, alternating with each other, and separated by the last. This rock sometimes contains cavities whose sides are lined with drusy crystals of quartz and topaz.

The texture of this rock is slaty granular. Topaz rock is very rare; it has hitherto been discovered only in Saxony, where it forms a mountain called Schneeckenstein, which reposes on granite. It contains no metallic substances. It is supposed that the rock from which the beryls of Siberia are obtained is of a similar nature.

11. *Quartz.*

This is to be considered as a simple rock, excepting that it is sometimes accidentally mixed with mica, and rarely with feldspar. It is usually of a compact and granular texture, but sometimes it becomes slaty, when it is called schistose quartz.

This rock contains no metallic substances, excepting what seems to be accidentally interspersed in it. Quartz of a granular texture forms considerable mountains in some parts of the north of Scotland, and particularly in the islands of Islay and Jura, where it constitutes the basis on which the prevailing rocks of those islands seem to rest. Beds of quartz are also not unfrequent in argillaceous and micaceous schistus, and in gneiss.

12. *Siliceous Schistus.*

This rock, which has been already described, forms considerable masses, which are traversed by quartz veins, and are disposed in beds in argillaceous schistus.

13. *Gypsum.*

Gypsum, as connected with the primitive rocks, is but rare; but it has been found in beds in micaceous schistus near Bellinzona in the Swiss Alps. It is mixed with mica, which gives it a slaty texture; and by this it is distinguished from the gypsum which is met with in other rocks.

CLASS II. *Secondary Rocks.*

The rocks included in this class are the following; 1. limestone; 2. gray wacken; 3. trap; 4. sandstone; 5. chalk; 6. gypsum; 7. rock-salt; 8. coal: 9. ironstone; 10. trap. The three first of the rocks now enumerated, namely, limestone, gray wacken, and trap, are denominated by Werner, for the reason already assigned, *transition rocks*, and constitute his second class.

1. *Limestone.*

This limestone is a simple rock, which is sometimes granular and sometimes compact, according as it approaches to the primitive or stratified limestone, between which it is supposed to be intermediate. It has a splintery fracture, and is slightly translucent. It exhibits various colours, sometimes red, or even black, veined with white. The white colours are veins of calcareous spar. It rarely contains any accidental substances, excepting at the upper part of the beds, in which animal remains are discovered, of which the species are supposed to have become extinct. This limestone sometimes alternates with a kind of argillaceous schistus, and more rarely with beds of amygdaloid or toadstone, as in Derbyshire. In general it lies on argillaceous schistus; sometimes forms mountains, but they do not reach any considerable elevation. It is usually stratified, but the beds are very thick. It contains veins of metallic ores. The agreeable mixture of fine colours, which appears in this stone, has brought it into extensive use in architecture.

2. *Gray Wacken.*

Two kinds of this rock have been described, viz. common gray wacken and schistose gray wacken.

Common gray wacken.—This rock is composed of grains or pieces of quartz, siliceous and argillaceous schistus, cemented by a substance of an argillaceous nature. The grains are sometimes very small, and sometimes of the size of a nut, or even larger.

Schistose gray wacken.—This is a simple rock of a slaty structure, which, in its composition and texture, is nearly allied to argillaceous schistus; but it is essentially different from that rock in its position, which is always connected with common gray wacken, and because it is never interrupted, like argillaceous schistus, with beds of chlorite schistus. It contains, besides, no grains of quartz, schorl, feldspar, or garnet, but is mixed with mica in small scales. It is rarely of a bluish or greenish colour, but most commonly of a dirty gray. Schistose gray wacken forms beds, which alternate with those of the first variety.

Gray wacken rocks are traversed by veins of quartz in different directions. They contain sometimes remains of shells and impressions of reeds.

These rocks are distinctly stratified; but the direction of the strata is not parallel to those of the other rocks on which they rest. This rock is rich in metallic ores, as in the Hartz, where there are extensive veins of lead and silver in gray wacken. In Transylvania, the same kind of rock is remarkable for rich ores of gold.

3. *Trap.*

Beside the primitive trap already described, two varieties of the same rock come under the secondary class. The first variety, or the transition trap of Werner, is essentially composed, as in the primitive trap, of hornblende and feldspar; but in the variety under consideration, the mixture is much more intimate; the grain appears finer, and the mass of rock seems to be homogeneous. The constituent parts of this rock are very often in a state of decomposition, which gives rise to many varieties. The two following are chiefly remarkable; amygdaloid and globular trap.

Amygdaloid.—This name is given to a compound rock whose principal mass is compact, and which contains imbedded in it, not only crystals of feldspar or quartz, which bring it under the denomination of porphyry, but nodules of other substances, or sometimes rounded empty cavities, the contents of which have been decomposed. This rock, therefore, is a mass of schistose hornblende decomposed, and similar to a kind of wacken, or ferruginous clay with fine grains. The cavities are sometimes empty, as already observed, and then their sides are lined with a kind of crust, and sometimes they contain grains or masses of quartz, calcedony, jasper, calcareous spar, and green earth. These nodules are very often hollow, having the interior walls lined with rock crystal. The amygdaloid or toadstone of Derbyshire, the nodules of which are commonly calcareous spar, belongs to this rock.

Globular trap.—This is a schistose greenstone partially decomposed, and reduced to a kind of fine grained wacken. It is met with in the form of large rounded masses, composed of concentric layers, the nucleus of which is of a harder nature, or less decomposed.

The rocks which come under this description are not distinctly stratified; they form insulated and conical mountains, and contain metallic ores, as those of copper, iron, and tin.

4. *Sandstone.*

Sandstone is a rock essentially composed of particles of quartz, sometimes of siliceous schistus, and very rarely of feldspar. These grains or particles are united together by a cement, which is sometimes argillaceous, with a mixture of iron, sometimes calcareous, or of the nature of marl, and more rarely siliceous. The proportion of this cement to the whole mass is variable, but it is never the predominant part in the composition of the stone. The size of the grains varies greatly; in some sandstones the particles are very large, when they come under the denomination of pudding-stone; while in others, the grains are so fine as to have all the appearance of a simple rock. Some of the varieties of sandstone contain vegetable and animal remains. This rock is distinctly stratified, and the beds of which it is composed are sometimes interrupted by beds of compact limestone, roe-stone, and coal.

Three varieties of sandstone have been described; the first is the red sandstone, which is supposed to be the oldest, and reposes immediately on gray wacken. The cement of this sandstone contains a considerable proportion of iron, to which the red colour is owing, and petrified wood is sometimes found in it. The second variety includes those sandstones which present different colours arranged in stripes or bands, and hence called *variegated* sandstones. It is in this variety that sandstone schistus or flagstone, and roestone, are usually met with. The third variety comprehends those sandstones which are commonly of a white colour, and have a calcareous or marly cement.

Sandstone in general is not very rich in metallic ores; sometimes, however, veins exist in rocks of this kind, and are chiefly filled with ores of cobalt. The red sandstone, which is covered by what is called a bituminous marly schistus, is in some places impregnated with copper ores, and particularly with the carbonate of copper; which is disseminated in the rock, giving it a green colour. Other metallic ores are sometimes also met with, but in small quantity.

5. *Stratified Limestone.*

This is a simple rock, composed of compact limestone, which very rarely contains any accidental substances, as crystals of quartz, pyrites, &c. Sea shells are, however, very common in this limestone, and hence it has been denominated *shell* limestone. This rock, which is distinctly stratified, alternates with beds of bituminous schistus, sandstone, and tuberculated masses of hornstone and flint, which are usually disposed in beds.

Several varieties of this limestone have been observed, and which seem to be distinctly characterised. The first, and what is supposed to be the oldest, rests immediately on red sandstone; and the lower strata, which contain many impressions of fishes, alternate with beds of bituminous marly schistus. The second variety, which is called shell limestone, from the numerous petrifactions found in it, is remarkable for having different kinds of petrifactions in the different beds. In the inferior beds the petrifactions are chiefly ammonites, belemnites, and turbinites. In the superior strata the remains of sea crabs, fishes, &c. are observed.

The rocks of limestone now described, are not unfrequently traversed by metallic veins, and chiefly those of lead and copper.

6. *Chalk.*

The strata of chalk, which in general are not very distinct, are characterised by containing beds of flint in tuberculated and detached masses, as well as numerous petrifactions of sea shells, particularly echinites, belemnites, &c. Many of these petrifactions have this peculiarity, that the matter of which they are composed is entirely siliceous. Chalk sometimes also contains globular masses of iron pyrites, whose internal structure is radiated. Scarcely any other metal or foreign substance has been discovered in chalk. Considerable masses of chalk are met with in some countries, as in France, England, and some of the islands in the Baltic.

7. *Gypsum.*

Beside the gypsum already described, which is connected with primitive rocks, this mineral is met with in extensive masses among the secondary rocks. The strata of gypsum belonging to the latter class of rocks, alternate with sandstone, swinestone, limestone, marl, clay, and rock salt. The beds of gypsum contain frequently crystals of different substances, chiefly quartz, arragonite, boracite, garnets, and is often mixed with sulphur, which is sometimes crystallized. They contain few petrifactions, but sometimes the bones of quadrupeds and birds.

Two varieties of stratified gypsum are described. The first reposes immediately on stratified limestone. It is composed of foliated gypsum, selenite, and compact gypsum, forming thin beds, and alternating with thin beds of swinestone. This variety of gypsum contains rock salt, and is the source of salt springs. The second variety of gypsum, belonging to the secondary rocks, is composed of different kinds of gypsum, but chiefly of fibrous gypsum, which alternates with indurated clay and sandstone. It reposes immediately on variegated sandstone, and is often covered by shell limestone.

Gypsum very rarely contains any metallic substances. Ores of copper, it is said, have been found in rocks of this description.

8. *Rock Salt.*

Rock salt might be more properly considered as constituting a part of the strata of gypsum and marl, rather than as forming a peculiar and distinct mass of rock, because it is usually imbedded in gypsum or marl, or is found to alternate with indurated clay, which is frqeuently impregnated with salt. It alternates also with limestone and swinestone.

9. *Coal.*

The nature of coal, and the different varieties of which it is composed, have been already described; and as we are afterwards to enter more particularly into the natural history of this valuable mineral, it would be unnecessary to dwell upon it in this place, or anticipate any part of the subject by detailing detached parts of it.

10. *Argillaceous Ironstone.*

This mineral is composed of an oxide of iron, combined with a considerable proportion of clay and other earthy matters. Argillaceous ironstone is disposed in beds, alternating with indurated clay, slaty clay, marl, sandstone, and some other rocks. They contain also frequently calamine mixed with galena, and sometimes impressions of plants and petrifactions of marine animals.

11. *Stratified Trap.*

The rocks which are peculiar to the mountains of trap of this description are basalt, wacken, pitchstone, basaltic tufa, amygdaloid, schistose porphyry, graystone, and greenstone. Other rocks also are sometimes met with in traps of this description, such as gravel and sand of different kinds, quartzose sandstone, clay, bituminous wood, coal, and some other substances.

Basalt.—This mineral has been already described as a simple rock; but considered as a mass, it is more or less of a compound nature. Very often it is of a porphyritic structure, containing chiefly grains or crystals of olivine, augite, basaltic hornblende, magnetic iron, sometimes leucite, feldspar, and quartz, as well as mica and calcedony. The structure of basalt is also sometimes amygdaloidal, and its cavities are then filled with zeolite, steatites, calcareous spar; sometimes the cavities are empty, and sometimes, it is said, they are filled with water. This rock frequently assumes a regular prismatic form, having from three to eight sides; sometimes it is of a tabular form, and more rarely in rounded masses, composed of concentric and distinct concretions.

Wacken.—This rock sometimes constitutes considerable beds, and seems to be intermediate between clay and basalt. It contains neither olivine nor augite, but sometimes crystals of basaltic hornblende, and particularly black mica, by which last it is characterised, and distinguished from basalt.

Pitch stone.—The pitch stone, which is met with in the rocks now under consideration, is of a black or greenish colour, and it is distinguished by having crystals of feldspar imbedded in it.

Amygdaloid.—The basis of this rock is a kind of clay, which seems to be a decomposed greenstone, and is sometimes penetrated with siliceous particles. It approaches very near to wacken, and, on the other hand, sometimes assumes a more compact texture, resembling basalt. The cavities of this stone are sometimes found empty, sometimes lined with an earthy crust, and sometimes filled with some foreign matter, which is frequently green earth, zeolite, calcareous spar, &c.

Basaltic tufa.—This substance is owing, it is supposed, to the decomposition of certain basalts, as it is found to contain fragments of rock of this description, particles of olivine, and some vegetable remains. All these substances are cemented together by a basis of clay, &c.

Schistose porphyry, or porphyry slate.—The base of this rock is clinkstone or phonolite, already described, having imbedded in it particles of feldspar, and more rarely of hornblende. It exhibits a schistose or slaty structure, and is frequently met with along with basalt.

Graystone.—This rock is composed of very small particles of feldspar and hornblende, so closely and intimately united, that it appears homogeneous. It is of an ash gray colour, and contains olivine and augite.

Greenstone.—This rock, as well as that which has been already described, is essentially composed of particles of hornblende and feldspar; but in the former, these substances are less distinctly crystallized, and more intimately combined together. This greenstone generally rests on beds of basalt.

Beside the two great classes of rocks, of which a short description has now been given, two others are usually formed by geological writers, namely, alluvial and volcanic rocks.

The alluvial rocks are composed of earthy and stony matters, which are the remains of former rocks worn down and removed by the action of the air and water, and deposited nearly in a horizontal position on the surface of the earth. Indeed the greater part of the earth's surface is composed of such depositions. Two kinds of alluvial depositions have been observed, such as take place in the mountains, and such as cover the plains. The mountainous alluvial depositions are formed, either in the valleys, or the flat ground of elevated regions. The first are in general composed of the remains of the surrounding mountains, united by a base of clay or lime. In this alluvial deposition are found fragments of rocks, and especially such minerals as resist the friction of the substances, along with which they are deposited; such are sapphires, rubies, chrysolites, hyacinths, and other precious stones; and also some metallic ores, as those of tin, iron, and gold. The alluvial depositions, which are found on the flat land of elevated regions, are loam, clay, and other substances of the same nature.

The alluvial deposites which cover plains, are loam, clay, gravel, sand, turf, calcareous tufa, some species of coal, of wood, and other bituminous matters. Four kinds of alluvial depositions have been described.

1. The first kind contains chiefly gravel and sand, but very little clay. Sea shells, in some places, constitute part of the mass; and pieces of amber and particles of gold are sometimes found disseminated in it. Such depositions usually take place on the shores of the ocean, or at the mouths of rivers.

2. The second kind of alluvial depositions contain beds of different varieties of clay, among which potter's clay often predominates. Kidney form iron ore, and some beds of sand, are occasionally distributed in this soil, which occupies chiefly the low plains interposed between chains of mountains.

3. In the third kind of alluvial deposition the materials are almost exclusively derived from the decomposition of vegetable matters, and they consist of certain varieties of coal, turf or peat, bituminous wood and bituminous earth, with beds of morassy iron ore. Sand and clay are not very abundant. Depositions of this kind occupy the lowest places of plains and valleys.

4. The last kind of alluvial soil, is formed by the deposition of calcareous matter on vegetables, which give to the mass a spongy texture. Sometimes the form of the plant is retained. But beside the vegetable substances on which the lime is deposited, thus forming what is called calcareous tufa, the remains of terrestrial animals, such as land and river shells, are sometimes found in it. Calcareous tufa forms considerable beds in valleys, and in low flat land on the banks of rivers, and on the shores of the ocean.

But although the different kinds of alluvial depositions are thus separately described, their existence in nature is seldom so distinctly and accurately marked; for it sometimes happens that two, three, and even all the four kinds, are found in the same spot.

Volcanic rocks have been divided into two kinds; true and false, or pseudo volcanic rocks. The first including what are known to be volcanic productions, and the second referring to those rocks which have undergone some change from the action of accidental fire; as when beds of coal have been set on fire and burnt. The rocks of this description are porcelain jasper, burnt clay, earthy scoriæ, and some other matters. The first of these has been already mentioned, and the others are of too little importance to require farther notice. The nature of the substances ejected from actual volcanoes will come under consideration when that subject is introduced.

CHAP. II.

OF THE DISTRIBUTION AND RELATIVE POSITION OF THE MATERIALS OF WHICH THE SURFACE OF THE EARTH IS COMPOSED.

HAVING in the preceding chapter given a brief sketch of the nature of the materials of which the surface of the earth is composed, we are now prepared to inquire in what manner those materials are distributed. And without considering the soil with which a great extent of the more solid parts of the earth's surface is covered, and which consists of the different simple earths, particularly alumina, silica, and lime, mixed with vegetable and animal matter, all in variable proportions; it may be observed that the rocky parts, which are more properly the subjects of our investigation, are disposed either in a horizontal or vertical position. The greater proportion of those masses of rock is arranged horizontally: but this is not to be understood to be strictly the case; for many rocks which come under this description form a very considerable angle with the horizon. The vertical strata which traverse the horizontal rocks in various directions, and which are composed partly of stony matters, and partly of metallic ores, although bearing a small proportion to the first description of rocks, yet as they exhibit many striking characteristic features, require a separate consideration, I shall therefore, in the present chapter, 1. examine the distribution of the horizontal masses of rock; 2. the vertical strata composed of stony matters; and, 3. such as consist of metallic substances, or metallic veins. These will form the subjects of the three following sections.

SECT. I.

OF THE DISTRIBUTION OF THE HORIZONTAL MASSES OF ROCK.

In our inquiry into the distribution of the rocks which compose the surface of the earth, the order in which those rocks were described in the last section of the former chapter may be followed, beginning with the lowest, or the granite, on which all other rocks repose, and proceeding to the highest, or those which form the uppermost strata; or that order may be reversed, by taking the uppermost strata first, and proceeding to the lowest which have been discovered. Each of these methods seems to possess peculiar advantages, which are to be estimated by the nature, variety, and more or less accessible situation of the rocks of any district of country to be described. But as the first method has been already partially adopted, I shall still give it the preference in the limited view to which the present investigation is necessarily prescribed; and for the purpose of illustrating the various geological relations which exist among the different classes of rocks, I shall endeavour to select the most appropriate and accessible examples which have been observed in our own country.

1. *Granite.*

So far as geological researches have been carried, it appears that all other rocks rest upon granite; that is, it constitutes the lowest mass of rock which has yet been discovered. At the same time granite forms some of the most elevated parts in the highest chains of mountains of the globe. The lofty summits of the Alps, and of the Pyrenees, and the Carpathian and Norwegian mountains, are composed of granite.

The proportion of granite, compared with other rocks in Britain, is not great. In Cornwall it is the most common rock; a small quantity appears in Leicestershire and Shropshire; but it is unknown in the mountains of Wales, excepting a small portion in the island of Anglesey. In some places of Scotland, the extent of granite rocks is more considerable. The highest part of the Grampians stretching through the interior of the northern part of the kingdom, and dividing into different ridges, which terminate at Aberdeen and Peterhead, or proceeding more directly towards the north, reach almost to the Murray Frith, is composed of granite. A range of granite mountains has also been observed commencing not far from Dalmellington, near the head of the county of Ayr, and extending to the southward and eastward into Galloway. But the best examples of granite which Scotland affords, are in the islands of Arran and Mull on the western coast. In the former it constitutes the most elevated part of the island ; and in the latter the granite appears in a low situation, at the point of Ross opposite to Icolmkill. Some of the mountains near Wexford in Ireland are composed of granite ; and I have reason to suppose, from specimens which I have examined, and the appearance of the mountains at a little distance, that the elevated range on the west side of Loch Foyle, in the north of that kingdom, is formed of a red variety of the same kind of rock.

The stratification of granite has been a subject of controversy among geological theorists. On the one hand, those who maintain that all rocks were formed by deposition from water, derive an argument in support of their theory from the stratified appearance which, they assert, may be observed in granite; while, on the other hand, the defenders of the theory, that granite has been in the state of fusion by means of heat, contend that it exhibits no such structure. It does not, I believe, often happen, at least in this country, that opportunities occur to enable the observer to ascertain this point. Perpendicular cliffs of granite, by which the peculiarities of its structure may be discovered, are less common than in other rocks; and to this circumstance, connected with the usual anxiety to support a theory which has been once adopted, is probably to be ascribed the diversity of opinion that prevails relative to that structure. The granite rocks at the point of Ross, in the island of Mull mentioned above, exhibiting in many places nearly perpendicular sections, afford to the unprejudiced observer some instrucive information on this disputed point. In those rocks the appearance of stratification is sufficiently obvious; but the strata or beds being of great thickness, can only be distinguished when they are seen on a large scale. Were the sections of these rocks of more limited extent, the strata, which are in a small degree inclined from the horizon to the southward and eastward, would not be visible.

2. *Gneiss.*

Of the stratification of gneiss no doubt can be entertained. In describing it as a compound mineral, it has already been noticed, that the stratified form of the rock is distinct and well marked. Gneiss reposes immediately on granite; and between the strata are sometimes interposed beds of different minerals, such as granular limestone, slaty hornblende, quartz, and more rarely porphyry.

It has been observed, that mountains of gnesis are less precipitous than those of granite; and that they usually exhibit rounded summits.

This rock is found to be remarkably rich in metallic ores, which are distributed in it, not only in veins, but also in strata. It affords almost every kind of metallic ore. The productive mines of Saxony and Bohemia are in gneiss, as well as the celebrated silver mines of Kongsberg, in the southern part of Norway.

Gneiss is not a very uncommon rock, but at the same time it appears to be, at least in this country, of less frequent occurrence than granite. The best examples of this rock, which I have had an opportunity of seeing, are in the island of Rona, and the north end of the island of Rasay, two islands which lie to the eastward of Skye. The islands of Coll and Tirie, also two of the Hebrides, afford examples of gneiss, and it is frequently met with among the rocks in Shetland.

3. *Micaceous Schistus.*

It has been already observed, that micaceous schistus is essentially composed of quartz and mica, the feldspar being generally wanting, is of a slaty structure, and is always regularly stratified; but in some varieties of this rock there is a considerable quantity of feldspar, when it seems to approach very nearly to the characters of gneiss; and indeed I find, by inspecting different mineral cabinets, that it is sometimes confounded with the latter.

The strata of this rock, in different circumstances, exhibit various appearances. Sometimes they present a waved structure, when in some cases the stratification is twisted and warped in various directions, and sometimes they appear to be of a straight slaty structure; and then the micaceous schistus, having the ingredients of which it is composed very intimately mixed together, is of a uniform texture, and comes very near, excepting in a greater degree of hardness, to argillaceous schistus.

Micaceous schistus reposes on gneiss, forming mountainous chains of very considerable length, and, like the latter, the mountains of this rock are distinguished by rounded summits, but with more moderate acclivities, and less considerable precipices.

This rock is very abundant in many countries. The greater number of the rich mines in Sweden and Norway, as well as many of those of Saxony and Hungary, are situated in micaceous schistus. A chain of mountains, composed of this rock, stretches through Strath Tay and Strath Errick, in the interior of Scotland. But the islands of Arran, Islay, and Jura, on the western coast, afford the most interesting and extensive examples of micaceous schistus. In Arran it rests immediately on the granite, and forms many of the second class of mountains of that island. In Islay and Jura the micaceous schistus reposes on granular quartz; which latter, in this case, seems to occupy the place of granite or gneiss, and forms, as it were, the nucleus of those islands. Almost the whole of the rocks which skirt the shores of both islands, as well as the mountains of inferior height in the interior, are micaceous schistus. On the shores in general, no other kind of rock appears; but in the valleys or flat parts in the interior of Islay, the schistus is covered by extensive strata of granular limestone.

4. *Argillaceous Schistus.*

The rocks which come under the general denomination of argillaceous schistus are not limited to those of the primitive class; they appear also in the secondary class, but with characters which are considered sufficiently discriminative.

The primitive argillaceous schistus has a slaty structure, and is distinctly stratified. Sometimes it is found to contain beds of chlorite and hone slate, or to alternate with this latter; and by this it is characterised and distinguished from the secondary rocks of the same name.

Argillaceous schistus belonging to the primitive class reposes on micaceous schistus. Entire mountains are sometimes composed of this rock, and sometimes mountainous chains of a considerable extent; but in general the mountains have a gentle ascent, and are less steep and precipitous than those formerly described.

This rock is remarkable for being very rich in some of the metallic ores. The celebrated mines of quicksilver of Idria are in argillaceous schistus; and the immense mass of copper and iron pyrites in Pary's mountain in the island of Anglesey is disposed in a similar rock.

Rocks of argillaceous schistus are by no means of rare occurrence, and particularly in our own country. In many parts it is very common and very abundant. Some of the smaller islands of the Hebrides on the west coast are entirely composed of this rock; such, for instance, as Easdale, and numerous other islands in its neighbourhood, which have long furnished roof slate of the best quality, and on that account are known by the characteristic name of the *Slate Islands*.

Many of those islands have been long a source of great emolument to the proprietors, and have afforded employment to thousands of persons, in digging, shipping, and conveying slates to all parts of Britain and Ireland, and sometimes to more distant places. A few years ago, when I visited the island of Easdale, the workings were carried below the level of the sea; yet such was the importance of this quarry, that it was considered worth while to erect a steam engine to carry off the water.

In the same island I observed the strata to lie about an angle of 45° from the horizon, and inclining from north to south. The strata are intersected with veins of quartz; and in one place a considerable whin dyke traverses the island. Some quarries of excellent slate have been also within these few years opened in the island of Bute. The low hills on the banks of Lochlomond likewise furnish slate. In the neighbourhood of Dunkeld quarries of slate have been long wrought. In other parts of Scotland this rock is not uncommon, but it is usually of an inferior quality.

The slate of North Wales is supposed to belong to the secondary class of rocks, according to our arrangement, or to the transition rocks of others. It reposes on green stone; and, excepting veins of quartz and calcareous spar, accompanied by blende and galena, seems to contain no other extraneous minerals. Another variety of argillaceous schistus is distinguished by having impressions of organized bodies and figured pyrites. This variety is met with in Derbyshire, where it rests on secondary limestone.

5. *Limestone.*

Limestone is not uncommon in most countries of the world, and in some it is very abundant. Limestone exists both in the primitive and secondary classes of rocks; the first being distinguished by its crystalline texture and some degree of transparency, and the latter by an earthy appearance and complete opacity. Primitive limestone is sometimes subordinate to gneiss, that is, beds of this variety of limestone rest on the latter rock.

To the class of primitive limestones belongs chiefly the rich variety of beautiful stones known by the name of marbles. The most valuable of the calcareous marbles, for very different stones have been brought under the same denomination, are those which have been obtained, both in ancient and modern times, from Italy and some of the Greek islands. In hardness, durability, and colour, the Carrara and Parian marbles have been from the earliest times preferred to all others; and hence Carrara in Italy, and the island of Paros in Greece, have continued from time immemorial the chief sources of statuary marble. The marbles of Arragon in Spain, of Sienna, and of Syria, which are of a yellowish colour, have been long also in great estimation. The Florentine marble, with yellowish brown designs, exhibiting the representation of architectural ruins, and the breccia called Brocatello marble, which is composed of small fragments of yellowish, red, and purple limestone, cemented by white semi-transparent calcareous spar, are also greatly sought after, and much admired. Some of the British marbles are far from being destitute of beauty. The marble of Tiree is indeed not inferior to some of the more beautiful of the Italian marbles, were it not that the delicate flesh-coloured ground, as well as the green spots with which it is marked, are apt to fade on exposure to the air. The county of Sutherland in the north of Scotland also affords marbles, some of which possess considerable beauty. The island of Skye, and other parts of Scotland, furnish marble of inferior value; but some beautiful varieties are found in England, and particularly in Devonshire and Derbyshire. But some of the marbles must be classed with the secondary limestones, as the Lumachella marble, which is a grayish brown compact limestone, containing shells that still retain a good deal of the pearly lustre; and the celebrated fire marble of Carinthia, which is also a compact limestone of a grayish brown colour, and in which the implanted shells exhibit a fire colour, with a beautiful iridescent lustre. Some varieties of the latter marble are extremely splendid.

An extensive mass of primitive limestone runs through almost the whole of the interior of the island of Islay. This remarkable body of limestone, which reposes immediately on the micaceous schistus, has been already noticed by the Author in the preceding work. Primitive limestone is not uncommon in the Grampians and some other places of Scotland. A limestone of an excellent quality, and exactly similar to that of the Grampians, is dug out near Campbeltown, in the Cantire district of Argyleshire. This limestone is distinguished by a crystalline texture, and a blackish gray colour; but yields when burnt a white lime of considerable purity.

The magnesian limestone, examined and analysed by Mr Tennant, is abundant in Notinghamshire and Yorkshire; it extends from the vicinity of Worksop, in the former county, to Ferrybridge in the latter, a distance of no less than 30 miles. This limestone, which is also met with in strata at Bredon hill near Derby, and at Matlock in the same county, and not uncommon in Northumberland, is supposed to rest upon secondary limestone. In some rare cases shells have been found in it.

From an imperfect account which I have lately received of this stone, it appears to be regularly stratified; the strata or beds are in general not thicker than a common brick, and lie nearly in a horizontal position. The thickness of the whole mass, in several places where it has been dug through, is said to be from 20 to 30 feet; and in digging downwards, a marly substance has been found. It is observed that the limestone, as it approaches to the marl, is less pure, and consequently less fit for the purposes of manure, to which it is extensively applied in that country.

This stone has been long employed for the purposes of building. It is with this limestone that Westminster Hall in London is built; the celebrated minster of York, and the walls which surround that city, are built of the same stone.

Roestone, so called from the resemblance which some of its varieties bear to the roe of fish, exists in considerable abundance in some countries, as in Sweden and Switzerland, but particularly in Thuringia in Saxony. The Ketton stone of England, and the celebrated Portland stone, are classed with this variety of limestone. This limestone is sometimes employed as a manure, by breaking it down and exposing it to the action of the air. The quantity of clay with which it is intimately mixed, prevents it from being properly calcined, so as to convert it into quicklime.

The Portland stone derives its name from the island of Portland, which is situated in Weymouth Bay, in the British Channel. This stone extends over the whole island, which is 4½ miles long and 2 broad, and it is dug out in every part of the island; but the quarries of Kingston are the most productive. According to Mr Smeaton, from whom this account is taken, 9,000 tons of stone were supposed in his time to be dug out annually. The first stratum in the quarries is a blackish or reddish earth, about 1 foot thick; to this succeed 6 feet of *cap*, or stone of an inferior quality, because it is found unfit for exportation. The stratum of roestone, or freestone, as it is called, is universally covered with a stratum of *cap*. From the imperfect description of this latter, it seems difficult to say what is its precise nature; whether it be a coarser and harder kind of limestone, or whether it be a less perfect sandstone. It is, however, only employed for the more common purposes of building. Immediately under the *cap* lies the roestone or freestone, which is 10 or 12 feet deep, and beneath this bed there is flint or clay. In some parts an irregular vein of flint runs through it. The stratum of stone that is wrought for sale lies nearly parrallel with the upper surface of the island, and in general the cover of earth or rubbish upon it is thin. Several beds of stone lie in contiguity one above another, varying in thickness from 2 to 4 feet, and sometimes more. In the splitting and working of Portland stone, animal remains are often found, which are chiefly oyster and some other fossil shells.

Portland stone, it is said, was brought into repute in the reign of James I. That monarch, by the advice of his architects, employed it in the construction of the banqueting-house at Whitehall. After the great fire in London, it was brought into very general use by Sir Christopher Wren in the erection of various public buildings.

Some of the most splendid edifices in this country are constructed of this stone; as St Paul's Cathedral, the Monument, and almost every fabric of note in London; the New Custom-house, the former Parliament-house, now the national Bank of Ireland, and most of the buildings of Trinity College in Dublin.

Along with the secondary limestones may be classed the different varieties of marl, as the earthy marl, which is met with in beds, sometimes in secondary limestone, and sometimes in sandstone; indurated marl, which is chiefly found in beds alternating with secondary limestone, or forming nests in the latter; what is called shell marl, is either the earthy or indurated marl, which abounds with shells.

As connected with the above may be noticed a singular variety of limestone, or marl, denominated *bituminous marl schistus*, or *marlite*. This exists in beds in secondary limestone, and is often mixed with different ores of copper, particularly the vitreous and pyritical; and sometimes, but more rarely, with the green or blue carbonate of copper, and even native copper itself, and then it is worked as an ore of copper. But the peculiar circumstance connected with this marlite is, that it contains petrified fish, with vegetable remains regularly arranged in bands. The bodies of the fish are carbonised, and their scales are often plated with copper ore; and although the layers are very regular, it is observed that each fish is in a contorted position, from which it is inferred that it had suddenly undergone a violent death. This marlite is met with at Eisleben and Ilmenau in Thúringia, and Riegelsdorf in Hessia *.

6. *Trap.*

The rocks which come under this denomination are found both among the primitive and secondary classes. The varieties of rocks included under primitive trap, which are common hornblende, slaty hornblende, primitive green stone, and schistose green stone, have been already described.

Some of the varieties of rock included under primitive trap are found in great abundance in different countries. Common hornblende rock is frequently met with, either in gneiss, micaceous, or argillaceous schistus, in different places on the west coast of Scotland, as well as in some of the Hebrides. Common green stone is found also in similar places.

Among the secondary traps are to be reckoned

* Aikin's Dictionary of Chem. & Min. II. 67.

the amygdaloid of Derbyshire, which exists in that county in great beds.

To the secondary traps also belong basalt, wacken, schistose porphyry, basaltic tufa, another variety of amygdaloid and green stone. Of all the rocks now enumerated, the first, or basalt, is the most common, and most widely distributed. It forms of itself entire mountains, which sometimes rise to a considerable height and of a conical form. Basalt frequently assumes a regular columnar appearance. An example of this may be seen on the south-west side of Arthur's Seat, near Edinburgh; but the finest examples in this country, are those of Staffa, on the west coast of Scotland, and the Giant's Causeway in the north of Ireland. Numerous appearances of the same kind may be observed in other islands of the Hebrides. Extensive ranges of basaltic columns are also not uncommon in other parts of the world, as those of Velay and Vivarais in France, which are particularly described in the splendid work of Faujas De St Fond. Columnar basalt is also not unfrequent, according to Dolomieu, on the shores of Sicily; and hence it has been supposed to be lava ejected from the volcano, which has assumed this regular form. Similar appearances in Iceland and other volcanic countries have given countenance to the same opinion.

Wacken is composed of the mineral already described, mixed with crystals of basaltic hornblende. It is distinguished also by containing plates of black mica of a hexagonal form. No crystals of olivine or augite are found in it, and by this it may be distinguished from decomposing basalt. It is not uncommon in basaltic countries, and particularly in many places of Scotland.

Schistose porphyry, phonolite, or clinkstone, appears frequently to assume a columnar or tabular form. The south side of Traprene Law, in East Lothian, affords a good example of the columnar form of this stone. Schistose porphyry is also the prevailing rock in North Berwick Law in the same county. It also appears in some parts of the Pentland and Braid hills near Edinburgh, and is very common in the islands of Arran and Lamlash on the west coast of Scotland.

Basaltic tufa sometimes constitutes considerable beds, lying nearly horizontal, and alternating sometimes with basalt. This substance seems to originate from the disintegration of beds of basalt, as it is composed of pieces of this rock with fragments of olivine and vegetable remains, loosely cemented together by an argillaceous matter. In the island of Cannay, on the west of Scotland, there is an excellent example of a bed of basaltic tufa, in which I observed considerable masses of wood, some of which not only retained the fibrous texture, but seemed to have undergone very little change. When dried, it burnt freely in the flame of a candle. From the appearance of the fibre, it seems to be a species of oak.

Basaltic tufa is also met with in Arthur's Seat, in the vicinity of Edinburgh.

The variety of amygdaloid mentioned above has for its base a decomposed greenstone. The cavities of this rock are sometimes empty, but are often filled with green earth, zeolite, calcareous spar, calcedony, agate, &c. This rock is not unfrequent in basaltic countries.

The greenstone belonging to the secondary traps is also composed of hornblende and feldspar; but the crystalline appearance of the grains is less perfect, while the stratification of this rock is often very distinct. This greenstone is also common in countries where basalt is abundant.

The rocks now classed under secondary trap, often repose on secondary limestone, sometimes on sandstone, and even, it is said, they have been observed immediately connected with gneiss or granite. This class of rocks is in general destitute of metallic veins, but it frequently abounds with the remains of vegetables and marine animals.

7. *Serpentine.*

Serpentine is considered as exclusively connected with the primitive class of rocks. It rarely contains beds of other minerals; but it is often penetrated by veins which are composed of granular limestone, calcareous spar, steatites, asbestos, garnets, and sometimes copper and magnetic iron. Two varieties of serpentine have been described. The first, or noble serpentine, usually reposes on granite, gneiss, or micaceous schistus. This variety is found in Corsica, Italy, and Siberia, and particularly at Portsoy in Scotland. The beautiful serpentine which is found near the harbour of Portsoy is disposed in vertical strata, and accompanied with micaceous schistus, marble, and hornblende rock. From the description given of these strata, it appears that there is first a stratum of marble about 12 feet thick, which, as well as the rest, stretches in a north-east and south-west direction; to this succeeds a stratum of micaceous schistus, between 30 and 40 feet thick; the next stratum is serpentine, the thickness of which seems not less than 50 feet; to this succeeds a stratum of micaceous schistus, 50 or 60 feet thick. Where the latter stratum is in contact with the serpentine, it is almost entirely composed of quartz. The next stratum is of marble, not less than 40 feet thick, but it is divided nearly in the middle by a thin stratum of micaceous schistus. This is succeeded by another stratum of serpentine, not so thick as the former, but seemingly of the same nature. The rock which is in contact with this serpentine is schistose hornblende, traversed by veins of granite, running in different directions.

and varying in breadth from 1 to 8 feet. This hornblende rock forms the harbour of Portsoy, and continues to a considerable distance beyond it, but is divided by another stratum of serpentine of considerable thickness *.

The other variety of serpentine noticed above includes common serpentine, and is less penetrated by veins. This variety is met with in Saxony and other parts of Germany, but particularly in Cornwall in England.

8. *Porphyry.*

Some of the rocks which come under the denomination of porphyry, belong not only to the primitive, but also to the secondary class. Some of the latter have been already described, as the schistose porphyry, which is included under the secondary trap. Mountains of porphyry, it has been observed, are rarely stratified, and never inclose beds of other substances. Porphyry is not very rich in mineral veins, although some of the varieties are remarkable exceptions to this; for the rich mines of Schemnitz in Hungary are situated in an argillaceous porphyry.

Porphyry is not a very common rock in this country. It is, however, met with in some places

* Jameson, Min. of Scottish Isles, II. 270.

in Perthshire. Clay porphyry and pitchstone porphyry are not uncommon in the island of Arran; and a feldspar porphyry of considerable beauty forms the rocks on the west side of the island of Rasay, opposite the island of Skye.

9. *Syenite.*

This rock derives its name from the city of Syene in Upper Egypt, where it is found in great abundance. Syenite has been long celebrated as being employed by the ancients in architecture. It has usually been considered as a granite.

Syenite is commonly massive, and is more rarely stratified, or of a schistose texture. Sometimes, however, the strata are pretty distinct, and the schistose texture is also sufficiently obvious. This is particularly the case with a great body of syenite, which forms that part of the island of Islay called the *Rhins*. In the island of Oversa in that part of Islay, I observed not only the appearance of stratification, but also the schistose texture. There is a great mass of syenite on the east side of Lochbroom, not far from Ullapool, in the north of Scotland. In my geological researches among the rocks to the north of that village, a striking appearance presented itself. On one side of a fissure, the rocks were composed of syenite, similar to that which forms one side of the harbour; but on the other side there is a great mass of plumpudding stone, or breccia, composed chiefly of rounded pieces of siliceous stone, cemented by a substance which, from its great hardness, consists chiefly of siliceous matter.

10. *Quartz.*

Quartz, when compared with other rocks, does not appear, at least in this country, to constitute very extensive masses. In small proportions, however, it is not unfrequent, forming beds or veins in micaceous or argillaceous schistus, and sometimes also in gneiss and granite. But some very remarkable masses of quartz are found in Scotland, as in some parts of Ross-shire; and particularly in the islands of Islay and Jura, where that variety, which is distinguished by the name of granular quartz, or, by some writers, primitive sandstone, forms by far the greatest proportion of the rocks of those islands. The principal mountains, some of which rise to a great height in both islands, are composed of granular quartz. This rock, indeed, may be considered as the basis on which the other rocks of those islands rest; and as in some measure occupying the place of granite or gneiss, on which micaceous schistus usually reposes.

11. *Wacken.*

Gray wacken, or grauwacker, as it is denominated in the German, from which the word is derived, forms a very great extent of rock in different countries. It is very abundant in Scotland. Two varieties of this rock have been noticed; the common and schistose gray wacken. The latter is found in the form of beds, alternating with the former variety. The stratification of this kind of rock is commonly very distinct; and besides alternating with each other, alternations with limestone, trap, and siliceous schistus, have been sometimes observed.

This rock is very rich in metallic ores. The celebrated silver and lead mines in the Hartz are in gray wacken, and some of the gold mines in Transylvania are in a similar rock. The lead mines of Leadhills and Wanlockhead, and the antimony mine at Westerhall, in the neighbourhood of Langholm in Scotland, are situated in the same kind of rock.

Rocks of gray wacken are very common both in the northern and southern parts of Scotland.

12. *Sandstone.*

Three varieties of sandstone have been noticed. All the varieties are distinctly stratified; and in some beds there are found regular fissures which run in two directions perpendicular to the stratification, so that the stone is divided into the form of parallelopipeds.

The first variety is red sandstone, which reposes immediately on gray wacken. This sandstone is very common and very abundant in some places of Scotland. A great mass of it extends along the shore from Greenock on the west coast, nearly to Saltcoats, where it is succeeded by the strata of coal. The same variety of sandstone is met with in different places near the Murray Frith, in the north of Scotland. It is also not uncommon in different places of the south of Scotland, and is frequent in many places of England. Foreign minerals are often met with in this variety of sandstone, and particularly small fragments of reddle, and vitreous and other ores of copper. It is in this variety of sandstone that a carbonate of copper is found, which was formerly wrought near Gourock, a few miles from Greenock.

The second variety of sandstone is remarkable for the diversity of colours, arranged in spots or stripes, which it exhibits. This variety sometimes alternates with schistose sandstone or flagstone, and sometimes also with roestone. This sandstone rests on secondary gypsum, and is covered by secondary limestone. It is abundant in many places of Germany, and is supposed to be the same variety which accompanies the roestone of England.

The third variety of sandstone has a calcareous cement, and is of a light grayish or yellowish colour. This variety is never connected with gypsum, and does not alternate with flagstone or roestone It is not uncommon in the vicinity of the strata which accompany coal, so that it is abundant in different places of Britain.

13. *Gypsum.*

Three varieties of gypsum have been distinctly marked. The first, which has been already noticed, has been hitherto only met with in micaceous schistus among the Swiss Alps.

The second variety is disposed in beds, which alternate with swinestone, and sometimes with rock salt. It contains other minerals imbedded in it, such as quartz, arragonite, boracite, and sulphur. It is observed, too, that the greater number of salt springs proceed from this gypsum.

The third variety is distinguished by containing fibrous gypsum, which is not met with in the two former. The only organic remains which are found in this variety are the bones of quadrupeds. They exist also in the preceding. This variety of gypsum reposes on secondary sandstone, alternating with indurated clay and sandstone, and frequently covered with secondary limestone.

Gypsum usually forms banks and hills of no great elevation, in plain countries, or at the mouth of spacious valleys. It is very abundant in some countries, as in several places of Germany, Spain, and Poland, and particularly at Mont Martre in the neighbourhood of Paris. Gypsum is also met with in Pennsylvania in North America, and in considerable quantity in some places of England, particularly in Nottinghamshire, Yorkshire, Derbyshire, and Cheshire.

14. *Rock Salt.*

Rock salt is always accompanied with an indurated clay, which is generally much impregnated with the salt. The distribution of rock salt is usually between secondary gypsum and secondary sandstone. It alternates with beds of swinestone, gypsum, limestone, and sandstone. It often forms continuous beds of great thickness, and is also frequently met with in large solitary blocks. The beds of rock salt are for the most part below the surface of the ground. Sometimes, however, it is elevated into hills of considerable height. Cardona in Valencia in Spain is a mountain which is entirely composed of rock salt, and is not less than 400 or 500 feet high. In the province of Lahore in Hindostan, there is a mountain of the same mineral, which is said not to be inferior in magnitude; and the elevated regions of Peru afford rock salt at the height of 7000 feet.

Rock salt is not of very frequent occurrence; but at the same time it is not to be considered as a rare mineral production. It is met with not only in different parts of Europe, but also in Asia, Africa, and America. Rock salt is so abundant in the desert of Caramania, in Asia Minor, and the air is so dry, that it is employed as a material for building. It appears from the information of Hornemann, that this mineral forms the surface of a great part of the northern desart of Lybia.

The Polish salt mines at Wieliczka, about eight miles to the south-east of Cracow, have been long celebrated, and the most extravagant descriptions of the splendour of those spacious excavations have been given by travellers; so that, as Mr Townson observes, any account of them dictated by sobriety of judgment must appear dull and insipid. Those mines have been worked for more than 600 years; and before the partition of Poland in the year 1772, it is said that they furnished so considerable a share of the revenue of the king as to yield an annual profit, which usually exceeded L. 90,000 Sterling.

The following is an account of the strata which cover the salt in the Polish mines.

	Fathoms.
Vegetable soil, - -	2
Sandy clay, - -	5
Fine sand like Tripoli effervescing with acids, - -	3·5

Marl with sand, and containing fragments of sandstone, - -	9
Sandstone, - -	1
Marl mixed with salt in small particles and cubes, - -	20

At the depth of 20 fathoms in the above marl are found the masses of salt, which are disposed in the form of short beds, or rather immense detached blocks, which are imbedded in the marl. These blocks are of such a size, that in passing through the galleries formed in them, sometimes the upper, and sometimes the lower end only of a block may be seen; but often, though the galleries are 3 or 4 yards high, the breadth can only be observed, and even in some places the blocks of salt form the sides of the gallery for 15 or 20 yards. These blocks compose the upper bed of salt, and from them the whole of what is called the green salt is obtained. This salt, which is of a greenish or blackish hue, owes its colour to numerous fine particles of a substance which seems to be of the nature of argillaceous schistus scattered through it. This variety of salt, on account of its impurity, is retained in the country for home consumption. In this marl also blocks of sandstone are sometimes found imbedded, and the marl itself is strongly impregnated with salt. Lower down there is another bed of salt, called *szybicker salt*, which is in some places 2 or 3 yards thick, is of a purer quality than the former, and is exported to foreign countries. This variety of salt rock is disposed in very extensive beds. The mine has been driven in one place 600 fathoms from east to west, and 200 from north to south; and salt being still found, the utmost extent is yet unknown. The nature of the stratum beneath the szybicker salt has not been ascertained; for the miners, being apprehensive of increasing the quantity of water, have never proceeded to a greater depth. The greatest depth of the mines is 120 fathoms. (See Plate I. Fig. 1.)

It does not appear that the remains of organized bodies have been found in great abundance in the strata connected with the salt rocks now described. None have been observed, according to Mr Townson's information, in the szybicker salt, or the lower strata; but some have been seen in the marl which envelopes the blocks of green salt, such as bivalve shells at the depth of 36 fathoms, crabs claws at the depth of 40 fathoms, and charred coal mixed with salt and gypsum at the great depth of 100 fathoms.

A great deal has been said of the immense excavations in these mines; some of them, it is asserted, are so extensive, that a house of many stories high might be built within them. A chapel, which is still shown to strangers, is formed in one of the blocks of green salt. Every part of it, its altar, columns, pillars, arches, statues, and other ornaments, are constructed of the same material. In this chapel mass was formerly celebrated two or three times a-week; and probably from this circumstance it has been said that the workmen employed in the mines, to the amount of 500, live constantly below ground. It appears, however, that they are never longer in the mines than during their hours of working. Springs both of salt and fresh water are found in the mines. To keep the mines dry, the salt water is drawn up in leathern sacks, and is thrown away; the small quantity of fresh water which they afford is reserved for the use of the horses which are employed in the subterraneous operations. At the time Mr Townson visited them, 24 horses were constantly kept below ground. The mines of Wieliczka yield annually about 6 or 7000 hundred weight of salt *; but according to Peschier, the yearly product is not less than 170,000 hundred weight †.

Rock salt is found on both sides of the chain of the Carpathian mountains. On the north side of this chain it is met with in great abundance; first at Wieliczka, and then at Bocknia, which is 5 leagues to the south-east of Cracow. At this latter place the salt rock reaches the same depth as at the former, but the salt is inferior in purity.

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* Townson's Travels, p. 386.

† Patrin, v. 359.

The salt appears on the same side of the chain at Sambor, Moldavia, and as far as Okna; and all together 58 different places where salt is found have been enumerated. On the south side of the chain the salt rock begins at Eperies, stretches eastward through the county of Marmoruss and Transylvania, as far as Cronstadt. This whole extent of country, which includes the places now mentioned, is very rich in salt. An hundred and fifty-nine different places are enumerated, which afford rock salt or salt springs.

The extent of salt rock now mentioned, on both sides of the Carpathian mountains, is supposed by some naturalists to be a continuation of the same strata from Wieliczka on the north, as far as it stretches through Upper Hungary and Transylvania on the south side. But this supposition, according to the observation of Patrin, is not very probable, from the circumstance of beds of rock salt never having been found in primitive rocks, and the strata to the north and south being divided by the chain of the Carpathian mountains, which are primitive, being interposed.

The salt mines of the Tyrol are situated on the ridge of a high mountain, two leagues from Halle, on the banks of the Inn, and to the north-east of Inspruck. The salt found in these mines is in masses, which are composed of a mixture of salt, with a rock of an argillaceous nature, and containing portions of salt in all its beds. In one part of the mountain there is a very large mass of salt, which is free from any mixture of stony matter. A gallery of 260 fathoms in length leads to this mass of salt. The passage to this gallery is kept constantly locked, that no part of it may be removed, and the workmen are even prohibited from carrying off the smallest quantity. This apparently singular circumstance is thus accounted for. As the salt in this mine is in general very impure, and should be considered rather as a simple rock impregnated with salt, to extract the pure salt the whole is dissolved in water. To effect this, the entrance to the subterraneous excavations is shut up; they are filled with water, which is allowed to remain for several months; and being then completely saturated with salt from the surrounding rock, or from the masses of pure salt that have been left, this water is let off, and salt is obtained from it by evaporation. But the pillars or masses of rock which are left to support the roof of the excavations are thus partially dissolved; and being no longer able to resist the superincumbent pressure, they are crushed, and the whole extent of the strata to the surface of the soil sinks; but at the end of some years, when the rubbish has acquired a proper degree of solidity, and a new deposition of salt, which is often equally abundant as the first, has taken place, the operations are renewed with equal success.

Patrin has thrown out a singular conjecture to account for the changes and operations now mentioned. He supposes that the large mass of pure rock salt, which is so carefully left untouched in the interior of the mountain, may be regarded as a powerful magnet, which attracts from the atmosphere the constituent principles of common salt, and in this way promotes its formation and deposition *. The probability of this conjecture is not very obvious.

Spain affords rock salt in considerable abundance. Bowles, in his natural history of that country, has described three of the most important of the Spanish salt mines. The first is situated in an elevated and mountainous region, lying between the kingdoms of Valencia and Castille, in a gypseous territory of half a league in circumference. Immediately under the bed of gypsum, there is a solid stratum of rock salt, which runs parallel to the stratum which covers it.

The next mine is in Navarre between Caparosa and the Ebro, and is situated in a chain of hills stretching more than two leagues from east to west. These hills are composed of limestone mixed with gypsum. The mine is in the highest part of the chain, and occupies a space of about 400 paces long, and about 80 broad. In this mine the beds of salt alternate with gypsum and earthy matters,

* Mineralogy, v. 363.

but in some places the gypsum is wanting; so that the strata are composed only of earth and salt, and it is observed that they are sometimes disposed in an undulated form.

The third mine is that of Cardona or Cordona in Valencia, which is a mountain situated about 16 leagues to the north-west of Barcelona, and some leagues distant from the Pyrenees. This mountain is entirely composed of rock salt; it is about 3 miles in circumference, and about 500 feet high. No cracks, or fissures, or beds, are observed in it; and what is very singular, no gypsum, which is one of the most common minerals accompanying rock salt, is found near it. This huge mass of salt has nearly the same elevation as the neighbouring mountains. As the depth has not been ascertained, the nature of the rocks on which it reposes are unknown. The salt rock obtained from this mountain is in general white, some of it is reddish, and some of a bluish colour; and we are informed that it is employed in Spain to make snuff-boxes, vases, and various trinkets, like the Derbyshire spar.

The salt mines of Cheshire in England have been long celebrated. The salt springs of this county, as well as those of Droitwich in Staffordshire, were known to the Romans, who gave them the name of *Salinae;* and indeed, according to the tradition of the inhabitants, it is said, that not only the brine pits, but also the rock itself, was wrought by that people. If this were the case, the knowledge of the existence of rock salt in this country must have been long lost; for it was only in the year 1670 that the discovery of that mineral was again made in the neighbourhood of Northwich. Rock salt has been discovered and dug out in other places in the same neighbourhood, but in no other part of the kingdom.

The rock salt of Cheshire is found at the depth of from 100 to 140 feet below the surface of the earth. The first stratum of salt is from 40 to 60 feet thick, is quite solid, and can only be broken by means of iron picks and wedges. Sometimes the rock is blasted with gunpowder; by which means masses of many tons weight are detached. It has somewhat the appearance of brown sugar-candy. Beneath the first stratum of rock salt there is a bed of hard stone, composed of large veins of flag, mixed with some rock salt. The thickness of this stone is from 100 to 130 feet. The next stratum going downwards is salt, some parts of which are perfectly white and transparent; others are of a brownish colour, but the whole is purer than the upper stratum. The thickness is from 15 to 20 feet. Above the rock salt there is a bed of whitish clay. Gypsum also is found in some places covering the strata of salt.

The rock salt pits are immense excavations, some of which are not less than 320 feet in diameter; and in digging out the salt, massy pillars are formed out of the rock, for the purpose of supporting the roof, which is also of the same material, a thickness of about 20 feet of the salt being left for that purpose. Fresh air is conveyed to the mines by means of tubes and bellows. The mines are generally dry, even at the greatest depth, but sometimes brine springs burst into them, so that the pillars which support the roof, and the whole works, are destroyed. It is said that the pits in the neighbourhood of Northwich yield annually from 50,000 to 60,000 tons of rock salt, part of which is refined and purified in England, and part is exported to different countries of the world.

Rock salt is very abundant in Peru; and it is singular that it appears in that country in regions equally elevated as those which contain the mines of silver and mercury. This is a remarkable peculiarity, as rock salt is usually distributed in low situations.

15. *Chalk.*

Chalk is usually disposed in thick beds, which lie nearly in a horizontal position, and alternate with thin layers of flint. Sometimes flint nodules are irregularly dispersed through the beds of chalk; but the masses of the flint are also often disposed in pretty regular discontinuous strata.

Metallic ores are rarely met with in chalk; martial pyrites and iron ochre are the only metallic substances which it affords. The remains of organised marine bodies, however, such as echinites, glossopetræ, pectinites, &c. are found in abundance. The bones of amphibious animals, such as the heads and vertebræ of crocodiles, and some of the hard parts of land animals, such as the teeth of elephants, are sometimes also met with deposited in chalk.

The elevation of chalk hills is never very considerable; it rarely exceeds 3 or 400 feet. Chalk hills are particularly distinguished by a smooth regular outline, and a peculiar tendency to form cup-shaped concavities. In England, the ridges of chalk are always bordered by parallel ranges of sand or sandstone. Beds of fuller's earth are observed to alternate with the latter. Chalk hills are also peculiarly characterised on account of their remarkable dryness and rich verdure.

Chalk, when compared with other rocks, does not appear to exist in great proportion, but in some parts of the world it is very abundant. In the southern and eastern parts of England, chalk is the prevailing rock; and it has been observed that the chalk hills in England occupy a greater extent than in any other country. Their direction is nearly from east to west, and run parallel to each other; they are separated by ranges of sandstone and low tracts of gravel and clay. The most northern and loftiest range of chalk begins at Flamborough-head in Yorkshire, and runs in a westerly direction a distance of 20 miles. Near Grantham in Lincolnshire, some fragments of a ridge of chalk hills appear. The midland counties are traversed by two ridges, which, proceeding westward, approach nearly to the borders of Oxfordshire. In that part of England south of the Thames, there are also two ridges of chalk hills; the one commences at the north and south Foreland, and passes through the north of Kent, the middle of Surrey, and the north of Hampshire; the other ridge commences near Hastings, and at the lofty promontory of Beachy Head, and passes through Sussex, and the south of Hampshire, into Dorsetshire *.

In the northern part of France, opposite to the English coast, chalk is also very abundant. It is also met with in Poland; and some of the Danish islands in the Baltic are chiefly composed of the same rock.

* Aiken, Dict. of Chem. & Min. I. p. 283.

SECT. II.

OF WHIN DYKES.

It has been already observed, that the materials which compose the surface of the earth are disposed in strata which are horizontal, or nearly so, or in vertical strata. By vertical strata are here to be understood such as traverse the horizontal strata in some direction different from the line of bearing; and in this view metallic veins might also be included. But although the analogy between metallic veins and vertical strata composed of stony materials, is in many points extremely obvious, and geologists have considered them as formed by the operation of similar causes, I propose, in the present section, to limit my observations to the latter. The general history of metallic veins will be treated of in the following section.

Names.—Vertical strata composed of stony matters have received different denominations, which appear in some measure descriptive of the nature of the substances of which they are formed, or of the seeming effects which they have produced on the intersected horizontal strata. Thus, they are termed *basaltic veins*, *trap dykes*, *whin dykes*; and in the coal countries of Scotland, they are called *gaws*, from the idea that they have occasioned the separation of the coal and contiguous strata through which they run.

The history of these dykes has been more carefully traced in coal countries than when they occur elsewhere; because on the accurate knowledge of their course, inclination, and thickness, depend, in a great measure, the judicious and successful operations of the miner, when his workings approach the dyke, or require it to be perforated, to regain the strata of coal on the other side. They have, however, been also observed and traced in other places, where a great extent of the horizontal strata has been exposed in the beds of rivers; as in the bed of the Water of Leith above St Bernard's Well, and on the sea shore, especially on the western coast of Scotland, where the rocks are very abrupt and precipitous, and where the violence of the Atlantic Ocean has worn down the horizontal strata, and left the vertical strata remaining in many places like immense walls or dykes. Hence probably the origin of the name; and as they often consist of that species of stone called *whinstone*, this epithet has been added.

Course.—When I first directed my attention to the history of whin dykes, I concluded that they had all nearly the same course: but this opinion, it soon appeared, was founded on partial observation; for I have since observed them running in almost every direction. Of the greater number, however, which I have had an opportunity of examining, the course generally lies between the points of the compass south and south-east, and north and north-west. This is most frequently the course of the whin dykes of Islay and Jura; it is the course of a remarkable one which traverses the coal strata at the village of Stevenston, near Saltcoats in Ayrshire, part of which is seen on the surface, not many hundred yards to the north of the west end of that village; and it is the course of two dykes which are still more remarkable in the island of Great Cumbray in the Frith of Clyde. These latter rise above the surface like huge walls, and are distinctly seen from the opposite coast of the main land near Largs.

It will perhaps appear that the most frequent direction of dykes of considerable magnitude is north and south, or a few points deviation from that course; and if this point be established by a fuller and more accurate history of dykes, the analogy between them and metallic veins will be more complete. For it is observed of the latter, that the most powerful, that is, the most productive, run from north to south. Dykes do not always proceed in a straight line, but form in their course certain flexuosities. In this winding course, however, the deviations are usually so small, as to have little effect on the general direction of the dyke, which upon the whole may be considered as nearly the same. A very remarkable dyke has been discovered in the coal field in the district of Boulogne in France. This dyke runs in the form of a crescent from north to west *.

The continuity of dykes is sometimes interrupted, exactly in the same manner as frequently happens to the horizontal strata, and which in technical language is termed a *slip*, and sometimes a *shift*. Slips of this kind are not unfrequent in coal countries; the extent of the slip is sometimes only a few inches, sometimes it reaches to many feet, and sometimes even to a number of fathoms. In all other respects the separated strata continue the same, having the same thickness, and the same inclination to the horizon. In the island of Islay I observed two dykes of this description, the one on the south side of Lochindaal, near the point of Laggan; the other on the shore of the south-east part of the island, a little to the south of the house of Ardmore. In both these dykes the extent of the separation or slip is just equal to the thickness of the dyke; the opposite sides are brought exactly into the same line; and after this separation, both dykes, so far as I could

* Journal des Mines, No. 1. p. 57.

trace them, preserve the same thickness, course, and inclination as formerly. See Fig. 2.

Inclination.—The direction of dykes downwards is seldom perpendicular; and this deviation from a line perpendicular to the horizon is called their inclination. Miners employ a different term to express the same thing. By them the inclination of a dyke or vein is called its *hade* or *hading*. If a dyke or vein run north and south, it is then said to have a north or south course or direction; but in its descent downwards, if it incline to the eastward, the inclination, *hade* or *hading*, is said to be easterly. The inclination of different dykes, and even of the same dyke, is various, sometimes approaching to the perpendicular, and sometimes deviating from that line.

The extent of dykes downwards seems not to have been ascertained with any degree of accuracy, and I believe the termination of very few has yet been discovered. The depth to which researches of this kind can be carried, is comparatively small, and with all the ingenuity and power of man, investigations to determine this point will probably always be limited by the extent of his mining operations. The crescent formed dyke mentioned above, which traverses the coal field in the district of Boulogne in France, and which consists of a species of marble, found in several quarries in the vicinity, has been traced to the perpendicular depth of 600 feet. At that depth it is succeeded by a rock of schistus, which, retaining the same course and inclination, continues to intersect the horizontal strata.

Extent.—The extent of dykes in length has not been accurately determined. Indeed it must be extremely difficult to follow their course with any degree of certainty; for those which are observed on the sea-coast, where they are most conspicuous, soon disappear in the mountains on the one hand, or on the other are lost in the sea; and as the extent of the same coal field rarely exceeds a few miles, dykes have seldom been traced beyond its limits: and in many cases the change in the nature and arrangement of the strata renders such an investigation almost impossible. Some dykes, however, have been traced to a very great extent. One in particular, on the banks of the river Meuse in the Netherlands, has been followed in its direct course to the distance of 4 leagues; and of this dyke it is observed, if pursued through all its windings, the extent cannot be less than 6 leagues*.

Thickness.—The thickness of dykes is various. Sometimes they are observed no thicker than a few inches; from that they increase to 1 foot, 6 feet, and very often are found from 10 to 20 feet. There is a dyke in the island of Islay, of the enormous thickness of 69 feet. This immense dyke

* Jour. des Mines, No. 13. p. 74.

accompanies a lead vein about a foot thick, which is included between it and the limestone strata. In this mining field two whin dykes, one of them 10 feet thick, have been discovered crossing the metallic veins. Dykes composed of a stone to which the name of quarry stone, from its use in building, has been given, run in various directions through the mining field of Leadhills. They are from 10 to 24 feet in thickness, are observed to be nearly perpendicular, and are traversed by the metallic veins, which is contrary to what takes place in the whin dykes in Islay, mentioned above. At the place where the metallic veins cross the dyke, the latter exhibits the appearance of a confused mass, but at some distance from the metallic vein it recovers its form and arrangement.

In going downwards, dykes are said to decrease in thickness, which is particularly observed of dykes of smaller magnitude; and of those of the latter description, it is also said that they diminish in thickness towards the extremities *. But among the numerous dykes which I have examined in this country, I have had no opportunity of verifying the fact of the diminution of the thickness of dykes, either in going downwards, or in their longitudinal extent.

* Jour. des Mines, ibid. p. 85.

In one respect, some whin dykes which I have observed are exactly analogous to metallic veins, in having branches, or, in the language of the miner, *strings* going off, and traversing the contiguous strata, and forming in their course an acute angle with the principal dyke. I observed a whin dyke of this description in the island of Jura, on the shore of the Sound. The diverging branch terminated in a point among the horizontal strata, at the distance of a few feet from the great dyke, assuming altogether a wedge-like form. In a dyke which traverses the strata in the bed of the Water of Leith, a little above St Bernard's Well, a string or branch passes off nearly at right angles, proceeds to a little distance from the dyke, and then forms another right angle; after which it makes another turn, forming a similar angle, and proceeding towards the dyke parallel to that part of the branch which first goes off.

Materials of dykes.—If metallic veins be included in the account, vertical strata or dykes may be said to be composed of every kind of mineral substance, but almost always different from the intersected horizontal strata. It is indeed by this last circumstance that their occurrence is at once recognised. In general, the dykes that are met with in Scotland, whether in coal countries, or on the western coasts and islands where they are so frequent, are of that species of stone which comes under the denomination of trap or whinstone.

Dykes consisting of other species of stone have also been found in Scotland.

On the Mull of Kinnouth, which forms the southern headland at the entrance of Lochindaal in Islay, I observed a small dyke of granite crossing the headland, which is composed chiefly of granular quartz. Vertical strata or dykes of granite have been observed in the island of Icolmkill, and in other places in the west of Scotland, and of pitch stone in the island of Arran.

Bergman, in his Physical Geography, supposes that granite never forms a component part of vertical strata. What has been already mentioned proves the contrary; and besides, granite dykes have also been discovered in other places. Dykes of this description were observed by Besson, on the great road between Limoges and Cahors in France, traversing horizontal strata of argillaceous schistus. These dykes, he observes, are from an inch to 6 feet in thickness, and the quartz, feldspar, and mica, are of larger size than are usually found in the granite of mountains *. Dolomieu makes a similar observation, and considers it as a discriminative character by which the granite of mountains, and that found in vertical strata, may be easily known; but it does not appear that this can always be admitted as a characteristic mark

* Jour. des Mines, No. 6. p. 22.

of distinction. The granite dyke noticed above, which traverses the granular quartz on the Mull of Kinnouth, in Islay, is small grained; and dykes of a similar description have been observed in other places.

A few years ago, when travelling on the coast of Ayrshire, between Wemyss bay and Largs, I discovered on the shore, near the house of Kelly, a very singular dyke. It is about ten feet thick, traverses the horizontal strata, which consist of pudding rock or breccia, whose cement is a red coloured sandstone, from north-east to south-west, and crosses a larger dyke of the whinstone of this country, nearly at right angles. This dyke is composed of very different materials, part consisting of common whinstone, and part of a breccia cemented by the matter of the dyke; and these alternate with each other, both in the thickness of the dyke and lengthwise. On one side there are 4 feet thick of whinstone; immediately in contact with this there is breccia 3 feet thick; and so on alternately across the whole dyke. In tracing the dyke lengthwise in the same line, there is found a few yards of whinstone, which is succeeded by a few yards of breccia, which latter in its turn is replaced by the whinstone.

Structure of whin dykes.—One of the most singular circumstances respecting whin dykes still remains to be considered. This is the peculiar structure, or arrangement of the parts of which they are composed; and it seems to have been little noticed by geological writers. Of this peculiarity of structure or arrangement, it may be generally observed, that it is in all respects the reverse of what takes place in the horizontal strata. When the dyke is of small magnitude, it is pretty compact in all its parts; but if an attempt be made to break or separate any part of it, the fracture will be found to run most readily in the perpendicular direction. But when the thickness of the dyke is more considerable, it usually forms several divisions, distinctly marked by perpendicular fissures; and there is often great variety in the nature and qualities of the several divisions of the same dyke. The exterior division of one side sometimes, and sometimes the exterior division of both sides, are of a softer texture than the intermediate division, and often contain in great proportion specks of radiated zeolite and calcareous spar; while the middle divisions are not only harder, but also more homogeneous. In other cases the reverse of this appears; the middle parts of the dyke are the softest and the least compact, and exhibit the greatest variety of heterogeneous substances.

Some whin dykes have a great tendency to assume, when broken, the prismatic form, which is the case with many, even of the most compact texture. In others, where the side of the dyke is exposed to view, and minutely examined, fissures may be traced, discovering the ends of pretty regular prisms; and in some dykes which I observed in the island of Jura, the prismatic columns are entirely separated, and lying loose: They are four, five, and six sided, and are jointed, the perpendicular fissures forming the joints; and excepting that they lie in the horizontal position, are in all respects similar to perpendicular basaltic columns. In one of the dykes which I examined in the island of Jura, the columns are from 12 to 18 inches in diameter. In some others, as on the sea-shore, near the house of Mr Campbell of Jura, and at the harbour of the small isles in the same island, the columns are of the enormous size of 10 and 12 feet in diameter.

A dyke which traverses the basaltic strata of the Giant's Causeway in the north of Ireland, exhibits in a still more remarkable manner this peculiarity of structure. The smallest masses detached from it assume the columnar form, and most of them are perfectly regular. The divisions invariably run in the horizontal direction; the columns consequently lie in the same position, are 3, 4, 5, and 6 sided, and are generally of small size. Some specimens of this description now in my possession, and which I collected at that dyke, do not exceed one inch in diameter.

Coal strata intersected by a dyke.—The author of the preceding work has given a pretty full detail of the effects produced by dykes traversing coal strata. In this place, therefore, I shall only briefly mention the relative position of the strata of a coal field which are intersected by a dyke. This will render the history of whin dykes more complete.

Although the strata on one side of a dyke be perfectly fair and regular, if the workings be continued through the dyke, the same strata will not be found on the same plane on the other side. The whole range of the strata is in many cases either elevated or depressed; and it is here that the skill and caution of the miner must be employed in discovering the coal which has disappeared. In the successful prosecution of this discovery, it becomes of the utmost importance to know, whether, in the dislocation which has taken place, the strata on the other side have been elevated or depressed. Now there is a general rule, founded on experience and observation, by which this point may be determined. When a dyke is met with in the progress of working a coal mine, if it shall appear that the angle formed by the dyke with the plane of the stratum of coal is an acute angle, then the strata on the other side of the dyke will be found depressed; but if, on the contrary, the same angle be obtuse, the strata on the other side will be found elevated. The distance of elevation or depression is usually in proportion to the thickness and inclination of the dyke. In small dykes, the height of the elevation or depression reaches only to a few fathoms, or, in some cases, to a few feet; but where the dyke is of great thickness, the same height is far more considerable, exceeding twenty, forty, and even sixty fathoms.

In most cases, where a dyke traversing the strata of coal has produced a dislocation, the whole of the strata which accompany the coal are also elevated or depressed; and when they are discovered on the other side of the dyke, whether they have suffered elevation or depression, they are generally found to have the same inclination to the horizon, the same relative position to each other, the same thickness, and the same qualities as before. See Fig. 3.

But it does not invariably happen in all cases that a dyke traversing the horizontal strata produces a dislocation. Sometimes, but I believe more rarely than otherwise, the strata on both sides of a dyke continue fair and regular in the same plane, and discover no perceptible appearance of being either elevated or depressed. Whether those whin dykes, which are accompanied by a derangement of their strata, are distinguished by any peculiarity of character from those which seem to have produced no dislocation, or in what circumstances the former differ from the latter, I have not been able to learn. It might, however, be a curious subject of inquiry to geologists; and as such I would recommend it to those to whom opportunities of examining this point may occur.

In this sketch of the history of whin dykes traversing coal strata, a fact respecting the coal at the place of junction is too remarkable to pass unnoticed. In most, or rather, I suspect, in all cases where a whin dyke traverses the strata, the coal, as it approaches the dyke, is not only broken down, compressed in its bed, and mixed with small pieces of the contiguous strata, but it is totally changed in its qualities. It is entirely deprived of the bituminous part of its composition, and is therefore altogether unfit for the purposes of fuel. In the technical language of the miner it is usually called *foul* coal, and in some parts of Scotland *humph* coal. The coal usually continues in this state to some distance from the dyke on each side. This distance, it is said, is in proportion to the thickness of the dyke; where the dyke is small, the extent of *foul* coal on each side is trifling; but in powerful dykes, that is, dykes of great thickness, the extent of the *foul* coal is very considerable. According to the information which I have received from some miners, the extent of this *foul* coal on each side of the dyke is found to be nearly equal to one-half of its thickness; so that, if this be true, the whole extent of *foul* coal, on both sides of a dyke, is equal to the thickness of the dyke: but how far this is to be considered as a general fact, I have hitherto had no opportunity of ascertaining.

Vertical strata or dykes of sandstone are sometimes met with traversing coal strata; and in one instance of this kind, which I had an opportunity of examining, a very considerable dislocation of the strata has been produced, but no change has taken place in the nature and qualities of the coal on one side of the dyke. On the contrary, the coal on that side continues as pure and clean where it comes in immediate contact with the dyke, as in any other part of the field. The instance now alluded to is near Edgefield, in the Loanhead coal field, about six miles south of Edinburgh. A dyke composed of sandstone, black blaes, and iron stone, or nearly of the same materials as the strata which accompany the coal, traverses that coal field from north to south, and throws the coal no less than 60 fathoms out of its former line of bearing. The extent of the foul coal on the west side of this dyke is from 10 to 20 yards in some of the seams; but on the east side of the same dyke, the coal is found clean and fair. Similar instances of the same thing, I have been assured, are met with in the same field.

Beside the materials now mentioned, as constituting vertical strata, rock salt and coal have also been met with, traversing the horizontal strata, and forming dykes. Thus, it appears that small veins of rock salt are by no means of unfrequent occurrence in the salt mines at Aehlen, in the canton of Berne, in Switzerland *.

Veins or vertical strata of coal are of more rare occurrence. Two examples of veins of this kind have been recorded. A vein of coal was observed by Werner at Wehrau, in Upper Lusatia. He mentions it as a remarkable occurrence; and indeed it appears to be the only instance of the kind which he had met with. This vein of coal is situated in a sandstone rock, is about 18 inches thick, and is nearly in a vertical position. The vein contains several inches of pure coal, but the rest is mixed with sand. The same rock includes several other smaller veins of coal, which traverse it in different directions, and do not exceed an inch in thickness †.

But the author of the preceding work has given a more particular description of veins or vertical strata of coal. This is the other instance above alluded to, which our author very correctly denominates a great curiosity, and an extraordinary appearance, quite out of common experience. He observed those veins of coal at Castle Leod, in the Highlands of Scotland; and informs us, that they

* Werner's Theory of Veins, translated by C. Anderson, M. D. p. 75.

† Ibid. & Charpentier, Mineral. Geog. of Saxony, p. 7.

have every character and descriptive mark common to good rake veins, and that the coal is lodged in the cavities in the same manner as metallic ores exist in veins. In some places the veins were not above an inch in thickness; but from one place he dug out coal, which was clean and pure, and about a foot thick *.

SECT. III.

OF METALLIC VEINS.

In many points of view there is a very obvious analogy between whin dykes and other vertical strata, described in the preceding section, and metallic veins; and this analogy has led many authors to treat of both under the general denomination of mineral veins. But beside the diversity in the nature of the materials, with which metallic veins are filled, there are other differences which properly enough entitle them to a separate consideration. Metallic veins are in general less powerful

* Vol. i. p. 165.

than whin dykes and some other strata, that is, they are far inferior in thickness; they are less extensive in length, and probably in depth, and they are composed of a much greater variety of materials.

The nature, form, and other circumstances connected with the history of metallic veins, have been already very minutely detailed by the author of the preceding work *, under the denominations of rake veins, irregular rake veins, partial veins, pipe veins, flat and accumulated veins. These are probably local names, which were familiar only to the author; for descriptions of metallic veins, where distinctions of this kind are admitted, have been seldom given by writers on this department of natural history.

Metallic veins, like whin dykes and the other vertical strata already described, are contained in fissures of the horizontal strata. These veins traverse the strata in all directions. It has been supposed, and there seems to be some foundation for the supposition, that veins which run from north to south are more powerful, that is, they contain a greater proportion of metallic ores than those whose direction is different, and therefore are found to be more productive and more valuable. In many mining fields, it has been observed that

* Vol. i. p. 221.

the principal and most productive veins have a course from north to south; or when there is any deviation, it is not very far distant from that course, generally running from some points between north-east and north-west, and south-west and south-east, while the subordinate veins traverse the strata in all other directions. In Cornwall, according to Pryce *, the direction of the best veins is from east to west, or at least within a few degrees of that course.

The thickness of veins, both with regard to the proportion of metallic ores which they contain, and the earthy minerals with which those ores are accompanied, is extremely various. Sometimes the extent of the fissure is only a few inches, and sometimes the sides of the vein or the walls come almost into contact. In other cases veins reach to the thickness of a few feet, and sometimes, although more rarely by including the whole of the mineral matters with which the fisure is filled, they exceed some fathoms.

With regard to the extent of veins in general, it does not appear that any thing very precise can be stated. The space occupied by the same mining field, where the veins continue to be of the same nature, and to yield the same mineral riches, is usually confined within narrow limits. The boundaries of the celebrated mining fields of Leadhills and Wanlockhead in Scotland, do not

* Mineralogia Cornubiensis, p. 80.

much exceed the range of mountains which include the valleys where the operations are chiefly conducted. Mr Pryce has made a similar observation relative to the Cornish mines. "Though "the depth of fissures," says that naturalist, "is "unlimited beyond the power of man to follow "after, yet it appears in general that their fruit-"fulness for metal is distinct and limited *."

It would appear from pretty extensive experience, that veins are found to be richer in metallic ores at some distance below the surface, and that they become poorer when that distance in their progress downwards begins to be considerable. Some of the best and most productive veins at Leadhills afforded the greatest abundance of metallic ore at the depth of forty or fifty fathoms; but as that depth has gradually encreased, the production of ore has greatly diminished; and Pryce, whom I have just quoted, says, that the richest state for copper in the mines of Cornwall is between forty and eighty fathoms deep, and for tin between twenty and sixty. At the depth of eighty fathoms, he adds, a great quantity both of tin and copper is sometimes obtained; but the quality of the ore is found to be greatly inferior, or, as he expresses it, "decayed and dry for "metal †."

* Mineralogia Cornubiensis, p. 79.

† Ibid. p. 80.

It would appear too, that as the same vein traverses certain rocks, it varies greatly in thickness and in mineral riches. A curious fact in illustration of this point has been noticed in Derbyshire. The lead veins of that county are situated in limestone, the beds of which alternate with beds of toadstone, or amygdaloid. When the vein, after traversing the stratum of limestone, reaches the stratum of toadstone, it seems to be entirely cut off; and indeed till lately, it was a pretty general opinion that this was actually the case. The vein again appeared in the limestone under the toadstone, and equally rich as before. It appears, however, from the more accurate observations recorded by Mr Pilkington *, that the veins do really traverse the toadstone, but are so much reduced in thickness, and so rarely yield metallic ores, that this circumstance had formerly escaped notice, and led to the supposition that the vein was entirely cut off. Sometimes small pieces of ore are interspersed through the toadstone, and in the middle of it was found at one place a vein of ore ten inches wide. This point has been more lately investigated by Mr Watson, who says, that the veins containing ores in the limestone stratum generally pass through the toadstone, but seldom contain ores in the latter. Sometimes (but it

* View of Derbyshire, i. 57.

is said to be a rare occurrence) galena with blende, and some other minerals, are found in the toadstone; for the veins, while in that rock, are generally small, and chiefly composed of calcareous spar with some bituminous matter; and when they descend into the limestone under the toadstone, they resume their former thickness, and frequently become as rich as formerly in metallic ores.

The same vein in its course, either in the line of bearing, or in its descent through the horizontal strata, seldom observes a perfectly straight direction. It appears, indeed, that the more powerful veins approach most nearly in their course to a straight line. But in tracing the greater number of veins, they are found to pursue certain deviations from a straight direction. These deviations, however, are rarely so considerable as to produce any great difference in the general direction of the vein, if it be examined between two very distant points.

The direction of veins downwards is very seldom perpendicular. The extent of deviation from a perpendicular direction is in some cases small, while in others it is very great, varying from two or three degrees to no less than fifty or sixty; and thus approaching so nearly to the position of the horizontal strata, that veins of this description have been considered as constituting beds in the horizontal strata, rather than as veins contained in fissures, and traversing the latter.

In describing veins, miners have adopted a peculiar phraseology, of which it will be necessary to give a short explanation. Veins, it has been observed, rarely run precisely in a perpendicular direction. This being the case, when a person stands upright in the excavation of a vein of this description, the sides of it must obviously appear to be in an inclined position. The upper side of the vein is called the *hanging side*, or simply the *hanger*; and the lower side is called the *ledger side*, or simply the *ledger*. If a vein run from north to south, and be inclined to the east, and if a person enter this vein from the north, the ledger is in this case on the right hand, and the hanger on the left. Here it may be worth while also to explain the language employed by some foreign writers in describing the course of veins. According to this language, the miners compass is divided into twice twelve hours. Twelve and twelve correspond to north and south; six and six, to east and west; and the hours, as one, two, three, &c. to the intermediate points of the compass. Thus, for instance, a vein running north and south is said to be a twelve o'clock vein; a vein running from east to west, is called a six o'clock vein; and a vein whose course is north-west and south-east, is denominated a nine o'clock vein.

Metallic veins are observed to undergo the same kind of dislocation or derangement as whin dykes; and this dislocation takes place both in the line of bearing and in their descent through the strata which they traverse. Sometimes the deviation from their usual course is merely a separation of the vein to a certain distance on the one side or the other, without the intervention of any mineral stratum, and such as has been already described in the history of whin dykes, and illustrated in Figure 2. But it frequently happens that the dislocation is more considerable, and seems to be occasioned by the vein which is separated being traversed by a dyke, or vertical stratum composed of some earthy bodies, or by another metallic vein. The effect produced is somewhat similar to the derangement of the coal strata, where they are traversed by a dyke, and have at the same time been thrown up or down from their former level on the opposite sides of the dyke. The extent of the dislocation is usually in proportion to the thickness of the dyke or crossing vein. The nature and effects of the dislocations now described will be better understood by examining Fig. 4. and 5. In Fig. 5. the extent of the dislocation is considerably greater in the first interruption of the tin vein, on the right side of the figure, where the vein or dyke that crosses the tin lode is of greater magnitude than the interrupting vein in the middle and left side of the same figure. In Cornwall these veins or dykes are called *gossans* and *flookans*; and as they run in an opposite direction to the tin veins, they are distinguished by the epithet of cross lodes, *cross gossans*, or *cross flookans*.

In tracing the course of metallic veins, it is no unusual thing to observe the principal vein giving off smaller veins; which latter traverse the horizontal strata in a direction somewhat different from the vein with which they are connected, and gradually diminishing in thickness, at last entirely disappear. Sometimes the branch which passes off from the principal vein, divides into a number of still smaller branches before it is entirely lost. This distribution of the smaller branches of veins is seen at f f, Fig. 4. To these branches or smaller veins the name of *strings* is given, in the technical language of miners in this country. When a vein of no great thickness is observed to divide frequently into strings or branches, the miner entertains no great hopes of its duration or riches; for it generally dwindles to nothing, or at least becomes so unproductive as not to be worth the labour and expence. In some cases, however, a vein becomes uncommonly rich at the place of junction, where it is met by a branch or two branches going off from opposite sides of the principal vein. A remarkable instance of this kind, which occurred in the celebrated Susannah vein at Leadhills, is still spoken of with rapture among the miners of that place, where the junction of a branch or two with the principal vein encreased the thickness of pure ore to 14 feet. This extraordinary mass of mineral riches excited so much curiosity, that a chamber of the dimensions now stated was cut in the solid ore, and was visited even by ladies of high rank.

The whole thickness of a metallic vein is seldom or scarcely ever composed of pure ore. The metallic ore is usually accompanied with some earthy mineral; the quantity of which varies greatly in different veins in the same mining field, and even in different places of the same vein. It is almost unnecessary to add, that a vein is characterised for its riches or poverty, according to the greater proportion of metallic ore, and the smaller proportion of stony matter, or the reverse. The earthy minerals which usually accompany the lead ores in Britain, are heavy spar, fluor spar, calcareous spar, and quartz. Some of these substances usually line the walls or sides of the vein, and include the metallic ore; and hence they are denominated the *matrix* of the ore, the *gangue*, or sometimes *vein stones*. Cavities are very common in many metallic veins; and it is in those cavities that the beautiful crystallizations, whether of earthy or metallic matters, which adorn the cabinet of the mineralogist, are produced.

The arrangement of the different layers of which a vein is composed is different in different veins.

Sometimes the metallic ore occupies the middle space of the vein, and thus forms the middle layer; and sometimes the same space is filled with some of the earthy minerals which usually accompany the ore. As an example of the latter, I recollect having seen a vein of lead ore at Leadhills, which was included in a matrix of quartz, and separated in the middle by a layer of heavy spar. The arrangement of the different layers of a vein is sometimes very regular and uniform. Werner describes a vein in Saxony, composed of two layers of calcareous spar in the middle, and having no fewer than 13 layers of different minerals disposed in the same order on each side. The lateral layers consist of fluor spar, calcareous spar, heavy spar, galena, &c.*

The same mining field, although of no great extent, often exhibits a considerable variety in the nature of the metallic ores, and accompaning minerals with which the veins are filled. Thus, at Wanlockhead and Leadhills, which are in the immediate vicinity of each other, the difference now alluded to is very remarkable. The veins at Wanlockhead in general yield a greater variety of mineral substances, but are less powerful and less rich in galena than those of Leadhills. The proportion of antimony in the ore of Wanlock-

* Theory of Veins, Translat. p. 83.

head is so great, as to injure the quality of the lead, and therefore must be separated before the lead is brought to market; the treatment of the ore at Leadhills is attended with no such inconvenience or expence. A few years ago, white lead ore, or the carbonate of lead, in groups of acicular crystals, was very common in the cavities of the veins at Leadhills; but at Wanlockhead the tabular variety of carbonate of lead was most frequently met with in similar situations. In place of the antimony with which the lead obtained from the mines of Wanlockhead is alloyed, the lead produced at Leadhills, I understand, usually contains a greater proportion of silver.

In the district of Freyberg in Saxony, no fewer than eight different kinds of veins are described by Werner; and each of these seems to be distinctly characterised, not only by a diversity in the nature of the metallic ore, but also of the accompanying minerals.

The first is galena lead ore, which contains from one and a half to two ounces and a half of silver in the quintal. This ore is accompanied with arsenical pyrites, black blende, common and liver pyrites, copper pyrites, and sparry iron ore. The matrix or vein stones are quartz, pearl spar, and calcareous spar.

The second is galena, which is very rich in silver, and is accompanied with black blende, common and liver pyrites, a little arsenical pyrites, with red silver ore, brittle vitreous silver ore, and white silver ore. The vein stones are similar to the preceding.

The third is galena, which affords about an ounce of silver from the quintal. It is accompanied with common pyrites, black blende, and red iron ochre; and the vein stones are quartz, and some chlorite earth.

The fourth is galena, which contains from a quarter to three quarters of an ounce of silver in the quintal. It is accompanied with pyrites and sometimes brown blende; and the vein stones are heavy spar, fluor spar, quartz, and calcareous spar. This deposition is accompanied also with gray copper ore, copper pyrites and galena, having for vein stones a quartzose petrosilex or horn stone, heavy spar, and fluor spar.

The fifth consists of native silver, vitreous silver ore, white cobalt ore, gray copper ore, galena, which is very rich in silver, brown blende, and sparry iron ore; and the vein stones are heavy spar and fluor spar.

The sixth is composed of native arsenic, red silver ore, white cobalt ore, native silver, galena, pyrites, and sparry iron ore; and the vein stones are heavy spar, fluor spar, calcareous spar, and pearl spar.

The seventh contains hæmatites and specular iron ore, having for vein stones quartz and heavy spar.

The eighth affords copper pyrites, green copper ore, malachite, and red and brown iron ochre; and the vein stones are quartz and fluor spar *.

From the details now given, it appears that the different veins in the same mining district are composed of very different minerals, and even when they apparently consist of the same metallic ore, as, for instance, lead ore, yet the lead obtained from that lead ore contains very different proportions of other metals alloyed with it. But not only does this difference prevail in different veins; the same vein presents also, in different parts of it, a remarkable diversity of mineral productions. Thus, it has been observed in the mining field of Leadhills, that the quantity of yellow lead ore, or phosphate of lead, is most abundant near the top of the vein, and that it diminishes in proportion to the depth, till at last it disappears altogether. The variety of white lead ore in groups of acicular crystals was very common during one period of the operations in the cavities of the Susannah vein of the same field; but as the operations were carried to a greater depth, very few specimens of that admired mineral production were found. Some metallic veins in France are described as affording at the upper part of the

* Townson's Philos. of Mineralogy, p. 93. and Werner's Theory of Veins, Translat. p. 210.

vein iron, ore, farther down, silver ore, and at a still greater depth, copper ore *: and in some of the mines of Saxony, iron ore is also found next the surface, which is succeeded by copper ore, the latter being cut off by cobalt ore; and at a greater depth the cobalt gives place to silver ore. The last fact, on what authority I know not, is mentioned by the author †; and from this he infers, that the remarkable vein of coal which he observed at Castle Leod may probably be succeeded by some metallic ore. Patrin says, that he saw large masses of native arsenic in the bottom of the silver mine of Zmeof in Siberia. At the depth of about 100 fathoms, the arsenic is the only mineral substance in the vein; and although it is found to contain a small proportion of silver, the miners were obliged to abandon their operations, and even to cover up the mine, in consequence of the noxious vapours which arose from the arsenic. The same naturalist adds, that the veins of silver ore in Siberia generally terminate, at a certain depth, in ores of arsenic ‡.

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* Jameson's Mineralogy, iii. p. 238.

† Vid. vol. ii. 168.

‡ Hist. Nat. des Miner. iv. p. 142.

CHAP. III.

OF THE NATURAL HISTORY OF COAL.

In the present chapter, I propose to make some general observations connected with the natural history of coal; to treat particularly of some of the coal strata of Britain, of France, and other countries; and, lastly, to offer some hints relative to the methods of searching for coal. The topics now enumerated will form the subjects of the four following sections.

SECT. I.

GENERAL OBSERVATIONS CONCERNING COAL.

The whole of the strata of coal which have yet been discovered, when compared with the surface of the earth, are of very limited extent; and even in those countries where this valuable mineral is found in abundance, as in Britain, it occupies only a few small spots, which are usually situated in regions of the earth little elevated above the level of the sea.

All kinds of rocks are not to be considered as indiscriminately the repositories of coal; and among the rocks where it exists, certain classes afford it in greater abundance, and of a better quality, than others. Three classes of soils or strata which accompany coal have been described; and these strata are distinguished by peculiar characters: there is also a striking diversity in the nature and properties of the coal which they contain *.

1. The first kind of repository of coal is that which exists in alluvial land; and it possesses characters which afford sufficient marks of discrimination from the other repositories of that mineral. The strata which accompany coal of alluvial land are usually clay, sand, and gravel; the series and proportional thickness of which are very various. The strata or beds of coal in this kind of repository, rarely, or scarcely, ever preserve the

* Kirwan distinguishes carboniferous soils or the various sorts of earth or stone, which accompany coal, into four kinds, viz. argillaceous, arenilitic or sandstone, or both these combined together, trap rocks, and calcareous rocks.

same thickness through the whole of their extent. The same irregularity is observed in the parallelism of the accompanying earthy strata: they are usually subject to sudden elevations and depressions, which often take place in the same stratum. There is another circumstance by which the coal strata of alluvial land are distinguished; they are not interrupted by slips or dykes, as is the case with the coal strata in other soils. The varieties of coal which are usually found in this soil are most commonly lignite or bituminized wood, common brown coal, moor coal, and more rarely pitch coal.

This kind of repository of coal is not uncommon in different parts of the world. The Bovey coal, which is found near Exeter in England, exists in alluvial soil.

2. The second kind of strata or soil which affords coal, is that which is denominated from the prevailing rocks, trap, or basaltic soil. In this soil, the number of strata which accompany the coal is not very great, and their parallelism is less perfect than in coal strata in which sandstone is the principal rock. In this repository the coal is not covered with shale, but with clay or basalt; and in the latter no vegetable impressions, or animal remains, are found. The strata of rocks of which this repository is composed are, wacken, basalt, both in a columnar and amorphous form, green stone porphyry, and argillaceous iron stone. Dislocations, or slips of the strata, are rarely met

with in the series of rocks now under consideration, but whin dykes are frequently observed. The varieties of coal which are usually met with in this repository are, pitch coal, moor coal, coal blende or blind coal, and sometimes slaty coal.

Mines of coal of this description are not unfrequent in different places in the interior of France. A remarkable mine of coal in this kind of repository is met with at Meissner in Hessia. In the same kind of repository coal has been found in Bohemia, and at Borrowstonness and Bathgate in Scotland.

3. The third repository of coal is by far the most important, not only as the coal is generally of a better quality, but as it is found in greater abundance, and more accessible. This repository is essentially characterised by the strata of coal preserving their parallelism to a considerable extent. The strata which usually accompany coal in this repository are, indurated clay, different varieties of sandstone, bituminous shale, ratchel or rubble stone, a soft decomposing clay porphyry or green stone, known in this country by the name of rotten stone, argillaceous iron stone, marl, and secondary limestone: but of these strata it is to be observed, that the whole are not always found in different coal fields; and even when this is the case, they do not alternate in the same regular series, or retain the same thickness. On the contrary, not only is the thickness of the different

beds extremely various, but they succeed each other in a very different order; and some of the beds, but particularly the limestone, are entirely wanting.

But although beds of limestone are to be considered rather as a rare occurrence among the coal metals, it is no unusual thing to observe a mass of limestone lying on the outer edge of a coal field. This fact, which holds with regard to many of the coal fields in this country, seems to have been little attended to by geological writers. Thus, at the extremity of the coal field in East Lothian, there is an extensive mass of bluish coloured limestone, containing animal remains, which appears on the east side of the village of Salton, and still nearer the coal field on the banks of the river Tyne, in the estate of Pentcaitland. In both places a seam of very imperfect coal is met with, alternating with limestone, but no stratum of workable coal has been found near it. On the south and east sides of the coal field near the village of Riccarton in Ayrshire, there is also a very extensive mass of limestone of the same quality. A similar limestone is met with in the same circumstances to the north of the coal field near the village of Stevenston in the same county. Coal has been found under the bed of limestone, but of so inferior a quality, as scarcely fit to be employed as fuel in burning the limestone. Indeed, it may be observed in general, that the coal which is a companied with any considerable mass of limestone, is usually of a bad quality.

With regard to the other facts connected with the natural history of coal, the author of the preceding work has entered into so full a detail of the various circumstances by which they are characterised, that it would be unnecessary repetition to resume any farther account of them in this place; but to give the reader a more distinct view of the strata which accompany coal, and of the order in which those strata succeed each other, I shall insert the following tables of the coal strata in different places; and by a comparison of these, the varieties in the arrangement and thickness of the strata, will be readily discovered.

TABLE I.

Account of the strata in Croft Pit at Preston Hows, about 1½ mile to the south-west of Whitehaven *; the depth 108 fathoms.

	Feet.	In.
Soil - -	1	3
Soil and clay mixed -	4	9
Black soil - -	1	0
1. Brown soft limestone, resembling stone marl in irregular strata	9	0
2. Dark coloured limestone, harder	6	0

* Dixon's Life of Brownrigg, p. 113.

	Feet.	In.
3. Yellowish limestone mixed with spar	4	0
4. Reddish hard limestone -	2	0
5. Reddish hard limestone, but with finer particles -	1	6
6. Hard dark coloured limestone	1	4
7. Yellowish limestone mixed with spar	4	0
8. Soft brown limestone -	4	2
9. Soft brown and yellow limestone mixed with freestone -	2	6
10. Limestone mixed with yellow free-stone - -	2	0
11. Reddish soft freestone -	1	6
12. Red slate striated with freestone in thin layers - -	2	6
13. Red freestone - -	42	6
14. Soft red slate - -	0	6
15. Red slate striated with red freestone in thin layers -	25	0
16. Red slate striated with freestone	27	0
17. Strong red freestone, rather grayish	29	9
18. Lumpy red freestone speckled with white freestone -	0	9
19. Blue argillaceous schistus speckled with coal - -	0	9
20. Red soapy slate -	13	0
21. Black slate with a small appearance of coal under it -	1	0
22. Ash coloured friable argillaceous schistus - -	4	6

	Feet.	In.
23. Purple coloured slate striated with freestone - -	23	3
24. The same, and under it black slate	4	0
25. COAL I. - -	1	0
26. Soft whitish freestone -	10	2
27. Blackish slate a little inclined to brown - -	4	11
28. COAL II. - -	1	10
29. Blackish shale intermixed with coal	2	6
30. Whitish freestone -	8	6
31. Strong bluish slate mixed with gray freestone - -	3	0
32. White iron stone -	1	0
33. Freestone striated with blue slate	1	8
34. White freestone striated with slate in thin layers -	9	3
35. Dark blue slate - -	13	6
36. COAL III. - -	0	9
37. Dark gray shale -	15	8
38. COAL IV. with a mixture of slate 1 inch thick - -	2	0
39. Gray freestone mixed with iron stone - -	8	0
40. Hard white freestone -	15	6
41. COAL V. - -	1	0
42. Shale mixed with freestone -	8	0
43. Olive coloured slate adhering to black slate - -	2	4
44. COAL VI. - -	1	1

	Feet.	In.
45. Black shale mixed with freestone	8	8
46. White freestone mixed with slate	8	0
47. Dark blue slate - -	22	4
48. Coal VII. - -	1	3
49. Black shale mixed with freestone	7	6
50. Strong white freestone -	6	0
51. Brown iron stone -	3	0
52. Dark gray slate - -	6	0
53. Dark gray shale, with an intermixture of Coal VIII. about 5 inches thick - -	5	6
54. Light coloured slate mixed with freestone - -	5	6
55. Blue slate striated with freestone	10	0
56. Strong white freestone a little tinged with iron - -	2	6
57. Very black shivery slate -	10	3
58. Coal IX. strong, and of a good quality - -	0	4
59. Soft gray slate - -	0	3
60. Coal X. very black, burns well	0	8
61. Hard black shale -	1	7
62. Coal XI. mixed with pyrites	1	2
63. Argillaceous schistus, gray and brittle	3	0
64. Blue rough argillaceous schistus	4	6
65. Fine blue slate - -	3	0
66. Freestone mixed with iron stone	3	0
67. Black shivery slate -	6	0
68. Dark blue slate very fine -	5	6

		Feet.	In.
69.	Dark blue slate, very brittle -	0	6
70.	COAL XII. - -	2	6
71.	Soft gray argillaceous schistus	0	6
72.	Argillaceous schistus mixed with freestone - -	2	0
73.	White freestone with fine particles	7	0
74.	Blue slate striated with white freestone - -	4	7
75.	Light blue slate, very fine -	3	0
76.	Blue slate a little mixed with iron stone - -	12	0
77.	Black shivery slate -	1	0
78.	COAL XIII. - -	0	6
79.	Brownish hard slate -	9	0
80.	Strong blue slate tinged with iron stone - -	28	6
81.	Dark blue slate, rather inclined to brown, and brittle -	1	6
82.	Blue soft brittle slate -	0	6
83.	COAL XIV. - -	1	0
84.	Lightish gray argillaceous schistus, brittle and soapy -	4	0
85.	Freestone striated with blue slate	7	0
86.	Fine blue argillaceous schistus striated with white freestone -	4	0
87.	Black slate, with hard, sharp, and fine particles - -	3	0
88.	Blue slate, light and fine -	27	0
89.	COAL XV. - -	5	4

		Feet.	In.
90.	Soft gray argillaceous schistus	4	3
91.	Black shivery slate -	2	2
92.	Coal XVI. - -	1	3
93.	Strong lightish coloured shale	3	4
94.	Blue slate striated with white free-stone - -	3	4
95.	Iron stone - -	0	4
96.	Gray slate - -	3	9
97.	Strong white freestone -	5	6
98.	Freestone striated with blue slate	0	10
99.	White freestone -	1	3
100.	Freestone striated with blue slate	3	11
101.	Black slate - -	0	5
102.	Freestone striated with blue slate	1	4½
103.	Strong white freestone -	0	4
104.	Freestone mixed with blue slate, in thin layers -	2	4
105.	Strong white freestone -	0	5
106.	Grayish slate, of a shivery nature	6	0
107.	Freestone mixed with blue slate, in thin layers - -	4	0
108.	Very strong with freestone	5	3
109.	Fine blue slate -	2	3
110.	White freestone striated with blue slate - -	0	7½
111.	Fine blue slate -	0	4
112.	White freestone striated with blue slate - -	2	1

		Feet.	In.
113.	Freestone striated with blue slate, in fine particles -	0	10
114.	White freestone in thin layers	0	4
115.	The same, but more friable -	0	5
116.	Fine blue slate - -	2	1
117.	Coal XVII. - -	7	10

Table II.

Presents a view of the strata in Restoration Pit, St Anthon's Colliery, near Newcastle. The depth of this pit is 135 fathoms *.

		Feet.	In.
1.	Soil and clay - -	30	0
2.	Brown freestone -	72	0
3.	Coal I. - -	0	6
4.	Blue metal stone -	17	0
5.	White girdles - -	13	0
6.	Coal II. - -	0	8
7.	White and gray freestone -	36	0
8.	Soft blue metal stone -	30	0
9.	Coal III. - -	0	6
10.	Freestone girdles -	18	0
11.	Whin - -	10	6
12.	Strong freestone -	19	0
13.	Coal IV. - -	1	0

* St Fond's Travels, i. p. 140.

		Feet.	In.
14.	Soft blue till - -	11	0
15.	Soft girdles mixed with whin	23	0
16.	Coal V. - -	0	6
17.	Blue and black stone -	22	0
18.	Coal VI. - -	0	8
19.	Strong freestone - -	9	0
20.	Gray metal stone - -	10	0
21.	Coal VII. - -	0	8
22.	Gray post mixed with whin -	25	0
23.	Gray girdles - -	19	0
24.	Blue and black stone -	14	0
25.	Coal VIII. - -	1	0
26.	Gray metal stone -	12	0
27.	Strong freestone - -	36	0
28.	Black metal stone with hard girdles	18	0
29.	High main, Coal IX. -	6	0
30.	Gray metal - -	27	0
31.	Post girdles - -	2	0
32.	Blue metal - -	4	0
33.	Girdles - -	1	2
34.	Blue metal stone -	30	0
35.	Post - - -	1	0
36.	Blue metal stone -	18	0
37.	Whin and blue metal -	1	6
38.	Strong freestone -	21	0
39.	Brown post with water -	0	7
40.	Blue metal stone with gray girdles	14	0
41.	Coal X. - -	3	0
42.	Blue metal stone -	18	3

		Feet.	In.
43.	Freestone - -	4	0
44.	Coal XI. - -	0	6
45.	Strong gray metal, with post girdles	12	6
46.	Strong freestone - -	7	0
47.	Whin - -	1	0
48.	Blue metal stone -	8	7
49.	Gray metal stone with post girdles	16	5
50.	Blue metal stone with whin girdles	10	3
51.	Coal XII. - -	1	6
52.	Blue gray metal - -	3	8
53.	Freestone - -	12	7
54.	The same mixed with whin -	12	0
55.	Freestone - -	8	0
56.	Dark blue metal - -	2	0
57.	Gray metal stone and girdles	14	0
58.	Freestone mixed with whin	18	7
59.	Whin - -	1	0
60.	Freestone mixed with whin -	6	6
61.	Coal XIII. - -	3	3
62.	Dark gray metal stone -	3	6
63.	Gray metal and whin girdles	10	10
64.	Gray metal and girdles -	9	0
65.	Freestone - -	3	0
66.	Coal XIV. - -	3	2
67.	Blue and gray metal -	4	2
68.	Coal XV. - -	0	9
69.	Blue and gray metal -	12	0
70.	Freestone mixed with whin -	4	6

		Feet.	In.
71.	Gray metal - -	0	6
72.	Gray metal and girdles -	6	9
73.	Low main, COAL XVI. -	6	6

TABLE III.

Exhibits the strata met with in sinking a pit at Ilkeston in Derbyshire, 31¼ fathoms *.

		Feet.	In.
1.	Soil and yellow clay -	6	6
2.	Black shale - -	4	0
3.	Iron stone - -	1	6
4.	COAL I. - -	1	3
5.	Clunch - -	6	6
6.	Gray stone - -	9	0
7.	Blue stone - -	7	0
8.	Black shale - -	1	6
9.	Brown iron stone -	1	0
10.	Black shale - -	6	0
11.	Light blue bind -	6	6
12.	Burning shale - -	2	6
13.	Light blue clunch -	4	0
14.	Light blue stone - -	9	0
15.	Blue bind - -	2	3
16.	COAL II. - -	1	6
17.	Black clunch - -	0	4

* Pilkington, i. p. 82.

	Feet.	In.
18. Black jet, a kind of cannel coal	0	9
19. Lightish blue clunch -	2	5
20. Broad bind - -	7	6
21. Light coloured stone -	4	0
22. Grayish blue cank (a hard substance)	6	6
23. Very light coloured stone -	14	0
24. Strong broad bind -	4	0
25. Gray stone - -	7	0
26. Blue bind - -	4	0
27. Coal III. soft quality -	2	6
28. Black bind - -	6	6
29. Coal IV. soft - -	4	0
30. Black clunch - -	3	0
31. Light coloured clunch -	3	0
32. Broad bind - -	11	6
33. Black clunch - -	3	0
34. Clunch and bind - -	25	6
35. Coal V. - -	6	3
36. Clunch - -	3	9

Table IV.

Shows the strata discovered in Borland Pit at Dysart in Scotland, which was sunk in 1788 and 1789 to the depth of 46 fathoms.

	Feet.	In.
1. A coarse freestone - -	27	0
2. Coal I. called Sandwell coal	4	0
3. Blaes, the pavement of the coal	4	0

	Feet.	In.
4. Hard freestone - -	14	0
5. Blaes - -	9	0
6. Coal II. - -	0	9
7. Hard freestone - -	20	0
8. Blaes - -	5	0
9. Hard freestone - -	4	0
10. Blaes - -	18	0
11. Hard stone - -	2	0
12. Gray feaks or bands, *a sandstone* of a lamellated structure, with a mixture of clay and sometimes streaks of coaly matter -	9	0
13. Coal III. - -	0	9
14. Kirk-stone, a porous freestone with balls of iron-stone -	54	0
15. Blaes - -	4	0
16. Coal IV. - -	0	9
17. Blaes - -	4	0
18. Gray feaks - -	7	0
19. Hard freestone - -	2	0
20. Gray feaks - -	2	0
21. Hard freestone - -	2	6
22. Gray feaks - -	12	0
23. White hard bands - -	6	0
24. Blaes - -	3	0
25. Pier-stone, a very hard freestone	11	0
26. Blaes - -	26	3
27. Coal V. the main coal -	24	0

In the preceding Tables the local names are retained. Many of these, it must be acknowledged, are extremely arbitrary; but it will not be difficult to understand them by a comparison of the strata in the different Tables. It may be just noticed, that the gray-stone and blue-stone of Table III. are sand-stones; *clunch* is a bituminous shale, and *bind* is an indurated clay. The blaes of Table IV. is also a bituminous shale, and the gray *feaks* is a shivery foliated sandstone.

It is no unusual circumstance to find the remains of animals and vegetables, and particularly the latter, on the strata which accompany coal. Impressions of fishes, or of river shells, as mussels and land snails, are sometimes met with on the shale; but those of plants of the fern and grass tribes are most common. The sandstone also not unfrequently contains similar impressions, as well as the entire mass of the roots, trunks, or branches of trees, sometimes in a horizontal position, and compressed as if with great force into a flattened form; and sometimes in a vertical position, seemingly the same in which they existed in the living state. Such trees, it may be added, are entirely converted into the matter of the sandstone, excepting the bark, which is often changed into a substance of the nature of coal, and in many cases possesses all the properties of true coal. But although the remains of organized bodies appear both on the common and bituminous shale, the latter of which is almost in immediate contact with the coal, yet the coal itself rarely exhibits any vestiges either of vegetable or animal impressions. This is undoubtedly a very singular and unaccountable fact, and seems not very favourable to the opinion of the vegetable origin of coal, unless it be admitted by those who support that opinion, that the vegetable structure has been entirely destroyed during the process of nature in the formation of coal. It must not, however, pass unnoticed, that all coal is not destitute of vegetable remains. When the coal is of a laminated or slaty structure, as in the cannel or parrot-coal of this country, the impressions of plants of the grass or reed kinds are very common on the surface of the stratum of coal; and the organized structure is often so entire, that the fibres of which the plant has been composed may be separated into very fine filaments of a glossy or silky appearance. Sea-shells are very rarely found in the strata which accompany coal; a circumstance which must be considered as rather adverse to the opinion of coal being formed by deposition at the bottom of the ocean.

SECT. II.

OF THE COAL OF GREAT BRITAIN.

It has been already remarked, that the coal hitherto discovered on the surface of the globe is comparatively of very limited extent. Excepting only a few small spots, the remaining, and by far the greater proportion of the surface of the earth, affords no traces of the existence of that valuable mineral. The same remark is by no means inapplicable to Britain, in which coal, which gives life and vigour to her noble and stupendous manufactories, may be justly regarded as abundant; but when its extent is compared to that of the whole surface of the country, it will appear to be extremely limited. The principal places in England which afford coal in abundance are the counties of Northumberland, Durham, and Cumberland, Stafford, Derby, Gloucester, and South Wales.

Coal of Northumberland.—Coal is met with in many places of this county; but it is dug out in greatest quantity on the banks of the Tyne, in the vicinity of Newcastle, and in the adjoining county of Durham. As this coal is shipped at Newcastle, or the ports of Shields dependent on it, and as this has been for hundreds of years the chief source from which the immense consumpt of the metropolis of the kingdom and the eastern parts of England is supplied with fuel, it is better known by the name of Newcastle coal.

The relative position of the coal of Northumberland affords a good illustration of the general fact already noticed, that the strata of coal are bounded by limestone. If a line be drawn from Alemouth, in the northern district of the county, to a little west of Bywell, on the river Tyne, all the valuable strata of coal will be found on the east side of that line. The strata of coal on the west side of the same line, which are only from one to three feet in thickness, and of a very inferior quality, alternate with extensive masses of limestone. On the east side of the line now described, no limestone whatever appears, excepting a small patch of a different variety, which is found at Whitley near Tynemouth. This latter limestone runs in a south-westerly direction through the county of Durham. It is in this space, between the two ranges of limestone, that the coal of Northumberland and Durham is included; for the same breadth of coal may be traced through the county of Durham, stretching in the same direction, and bounded in a similar manner on the east and west by different kinds of limestone.

The coal strata of Northumberland and Durham incline or dip to the south-east; and there is perhaps no coal-field in the world of nearly the same extent, in which the strata lie so fair and regular; but this coal-field is not entirely free from dislocations. A very remarkable one, called the Main Dyke, runs in a south-westerly direction from Currie Point, about 5 or 6 miles north of Tynemouth, by New Benton, West Kenton, and Townly Main, and produces a downcast in the strata of no less than 90 fathoms to the north.

The various strata or seams of coal with which Northumberland and Durham abound, and the strata which accompany the coal, will be seen by consulting Table II. given in the former section. The depth of the different seams will also be found in the same Table. The coal of these two counties is wrought from 30 fathoms to 135 fathoms, which is the depth of the low main coal at St Anton's coalery, 3 miles east of Newcastle, from which the table of the strata is taken. But a pit has been sunk more lately at Willington, 5 miles north-east from Newcastle, where the depth to the low main coal is not less than 140 fathoms.

It appears that coal was wrought very early in the vicinity of Newcastle; and indeed some have supposed that a coalery was established not far from Benwell (the Condercum of the Romans) during the period in which that people lived in

Britain. In the year 1239. Henry III. granted to the freemen of Newcastle the right to dig coal in the neighbourhood, and 7 years after that time, it is said it first obtained the name of *sea-coal*. In the reign of King John, the coal trade made rapid progress; but although coal was found to be the best kind of fuel, it appears that its use was prohibited in London by a royal proclamation, which was issued in 1306. In 1351, a licence was granted by Edward III. to the burgesses of Newcastle, to dig coals and stones in a place called Castle Field, without the walls; and about the same period, a coalery at Elswick near Newcastle was demised to Adam Colewell, for five pounds of yearly rent. In the year 1421, the coal trade had become of such importance, that acts of parliament were made for its regulation; and in particular it was directed by one which was passed in that year, that all vessels carrying coals should be measured by commissioners nominated by the king, and should have their burden marked upon them, that his majesty might not be defrauded of his duty of twopence per chaldron by false measurement.

A lease for the period of 8 years, of two coal-pits at Elswick, was granted by the prior of Tynemouth in 1538 to Christopher Midford, at the annual rent of 50l. The price of coals at this time at Newcastle was 2s. 6d. per chaldron, and at London about 4s. In 1582, Queen Elizabeth obtained from the bishop of Durham a lease of the manor of Gateshead and Whickham, with the coal mines, common wastes and parks, for 99 years, at the annual rent of 90l. This lease, which is commonly known by the name of the *grand lease*, and which occasioned an increase of the price of coals, was first assigned to the earl of Leicester, the queen's favourite, and afterwards to the famous Sutton, the founder of the Charter-house in London. The price of coals then rose to 6s. per chaldron. An assignment of the same lease, for the sum of 12 000l. was made by Mr Sutton to Sir William Liddle and others, for the use of the mayor and burgesses of Newcastle. Coals then advanced in price to 7s. afterwards to 8s. and in 1590 to 9s. per chaldron. During the time of Queen Elizabeth, and the four succeeding reigns, various acts and regulations were made by parliament relative to the coal trade of Newcastle. In the year 1648, the price of coal in London was so high, that, it is said, many of the poor actually died for want of fuel. A complaint was made against Sir Arthur Hazlerigg, governor of Newcastle, for imposing a tax of 4s. per chaldron on coals; and the year following the matter was taken up by the house of commons, and an investigation directed to be made into the claim of 1s. per chaldron, and in what way this claim might be obviated.

In the year 1655, the price of coals in London exceeded 20s. per chalron; and at this time 320 vessels appear to have been employed in the coal trade upon the river Tyne, each of which carried annually 800 chaldrons. An act of parliament was made in 1667, by which a duty of 1s. per chaldron was granted to the lord mayor of London, to enable him to defray the expence of rebuilding the churches and other public edifices which were destroyed by the great fire of the preceding year; but this being found insufficient, it was raised to 3s. per chaldron, and to continue for 20 years. In 1677, Charles II. granted to the duke of Richmond a duty of 1s. per chaldron on coals; and the right to this impost continued in the same family till the year 1800, when it was purchased by government for the payment of 19,000l. annually to the duke and his heirs. The duty on coal imported into London amounts at present, it is said, to the annual sum of 25,000l.

Such is a short sketch of the coal trade of Newcastle till it rose to its present importance. The following is a statement of the quantity of coals exported from the river Tyne, for a period of 4 years; and it will show to what an extent it is now carried.

Years.	Coastwise.		Over Sea.	Plantations.
1802	Chal.	494,488	41,157	2,844
1803	ditto	505,137	42,208	1,516
1804	ditto	579,929	48,737	3,852
1805	ditto	552,827	47,213	2,360

But it must be observed, that the above is exclusive of the coal exported from the harbours adjoining to Newcastle, as from Sunderland, the exports of which amount annually to 300,000 chaldrons, besides a considerable quantity from other ports. It is also exclusive of the quantity consumed in the town and neighbourhood.

Our Author, it will be recollected, has thrown out some hints in the former volume, with regard to the probable duration of coal, in opposition to the opinion that the Newcastle coal, or in a more general view the coal of Britain, may be considered as inexhaustible; and to form a probable conjecture of the length of time during which a supply of coal may be obtained from the rivers Tyne and Wear, a calculation has been made according to the following data. 1. That the seams of coal which are now wrought in Northumberland and Durham may be estimated as equal to a seam or bed of 20 miles in length, and 15 in breadth; 2. That this seam may be taken on an average at 4½ feet in thickness; 3. That one sixth of the above extent of coal must be deducted for pillars, which are left in the mines; and, 4. That a cubic yard of coal is equal to 1 ton or 20 cwt. according to the experiment of Dr Watson.

The consumption of coal in London is estimated

	London Chald.
at - - -	900,000
Coastwise - -	700,000
Foreign consumption -	250,000
Consumed at Newcastle, Shields, and Sunderland - -	450,000
Total annual consumption of coal from the rivers Tyne and Wear	2,300,000

The number of tons in the above quantity, taking the chaldron at 27 cwt. is 3,100,000, and as a ton weight of coal occupies in the earth the space of one cubic yard, the number of entire yards in the square mile, amounts to - 3,097,600

The beds or seams of coal being taken on an average at $4\frac{1}{2}$ feet in thickness, increases the above number of entire yards in the square mile, by half the number of square yards, to	1,548,800
And hence the square mile contains of cubic yards, or tons of coal,	4,646,400
Deduct one sixth for pillars, waste, &c.	700,833
Tons of coal obtained form a square mile - -	3,945,567

From the above calculation, it appears that a square mile is sufficient for the consumption of

$1\frac{1}{5}$th year; and taking the area as already stated at 20 miles long and 15 broad, amounting to 300 square miles, there is a source of consumption for 360 years.

The above statement of the probable duration of coal in the counties of Northumberland and Durham is given according to the data laid down by Dr Macnab, in his Treatise on the Coal Trade; but it must be observed, that although the district of coal may be estimated at 300 square miles, yet as a considerable part has been wrought out, and no account of this taken, the calculation must turn out erroneous; and if to this be added the increase of the annual consumption, which there is good reason to think may be considerable, the period in which the whole coal of this district will be consumed must be greatly abridged. According to other calculations, indeed, the extent of the coal district in Northumberland and Durham is estimated at 25 miles long and 8 broad, making the superficial extent only 200 miles. But the calculation alluded to proceeds on the supposition that the whole mass of coal in that extent may be estimated at 3 yards thick; in which case the duration of the coal, at the same annual consumption, will be 400 years.

Of the calculations now referred to, it may be observed, that they are to be considered only as an approximation to a precise statement of the quantity and consumpt of this valuable mineral.

It is hoped, however, that they may prove the means of exciting farther investigation into a subject which is so closely connected with some of the fundamental resources of a nation which depends so much on its trade and manufactures; and may perhaps also be the means of economising this necessary fuel, not only in conducting the mining operations to obtain it, but also in the management of the numerous processes of art to which it is applied.

Whitehaven Coal.—This coal lies on the west side of England, in the county of Cumberland, and the valuable property of land which contains it came into the possession of the Lowther family in the year 1666, by a grant of Charles II. The inclination or dip of this coal is nearly to the west, and is equal to about 1 yard in 10. The strata are frequently interrupted by dykes and fissures, running from east to west nearly, and producing dislocations to the extent of 120 feet. In a depth from the surface of 165 fathoms, there are 7 large beds of coal, beside 18 thin beds, which are not worth the expence of working. The nature and thickness of the different strata, with the thickness of the different seams of coal, may be seen by consulting Table I. in the former section.

The beds of coal which have been worked at Whitehaven, as already noticed, are 7 in number; viz. 1. Crowband. 2. Little band. 3. Yard band.

4. Bannock band. 5. Main, or prior band. 6. Two feet band. 7. Six quarters band.

Two coaleries have been established on the mining field in the vicinity of Whitehaven. The situation of the Howgill coalery is on the west side of the town. It extends to the southward 2½ miles. The breadth is about 1½ mile, part of which runs under the sea for the space of 900 yards, thus making an area of 2300 acres. To the south and south-west, it is said, a more valuable field of coal still remains to be explored. The coal in this field is wrought from the depth of 40 fathoms to above 100; and in one pit, in which the sixth bed of coal is wrought, to the extraordinary depth of 149 fathoms. This latter is supposed to be the deepest coal-pit in Britain.

The other coalery established on this mining district is situated on the north-east side of Whitehaven. It extends in length, from west to north-east, above 3000 yards, and in breadth, from south to north-west, more than 2800 yards. The principal beds of coal in this part of the field are the 4th, 5th, and 7th. The 4th bed, which has not yet been worked, is 6 feet in thickness. The coal in the 5th bed is from 9 to 10 feet thick, and is 17 fathoms deeper than the 4th bed; the thickness of the 7th is from 4½ to 6 feet, and it lies from 38 to 44 fathoms below the 4th bed.

The operations of the miners have been often greatly interrupted in consequence of the fire damp, or hydrogen gas of modern chemistry, which is evolved in great abundance in these mines; and when its nature and effects were less understood, many fatal accidents happened in consequence of its sudden and unexpected explosion, by bringing into contact with it a burning body. It was a practice formerly with the workmen, with a view to prevent its accumulation, to set fire to it with the flame of a candle, which was cautiously introduced along the bottom of the mine; and when it had reached the extremity, it was raised to the roof, and being thus brought into contact with the inflammable air, an explosion took place, the effects of which the operator avoided, by observing the precaution of lying prostrate on the pavement or floor of the mine; but this method of dissipating the fire damp, which often proved a dangerous expedient, has been long abandoned, and an ingenious invention has been adopted for the same purpose. This is accomplished by means of a steel wheel, moved by tooth and pinion, which is turned round with great velocity, and strikes against a large piece of flint. The sparks which are produced by this collision give sufficient light to the workmen, and expose them to little or no danger*. But if my information be correct, even

* Dixon's Life of Brownrigg, p. 95.

this invention has been relinquished, and the fire damp is removed from the mines by promoting a free circulation of atmospherical air, and consuming the hydrogen gas. The only hint which I have met with of this method is contained in a short notice communicated to a periodical miscellany *, in the following words: "From a new system in airing the earl of Lonsdale's extensive coal works near Whitehaven, the miners have fortunately been free from any serious accidents for several years, although many new fields of coal have been opened out; and this process is always deemed a most dangerous part of the service. The hydrogen gas, inflammable air, or dirt as the workmen call it, is now made useful in carrying on the works. They have collected a very large quantity of it at the bottom of one of their upcast shafts, (duke pit) and keep it constantly burning. The heat from it exceeds that of their largest coal fires, or lamps as they are called, which are kept at the bottom of the upcast shafts to rarify the air in the pit. The speed of the common atmospheric air, by burning the hydrogen gas, is greatly accelerated. It compels it to travel at the rate of more than four miles an hour; whereas common air courses with coal fires at the upcast shafts seldom more than three

* Monthly Magazine, xxiii. 499.

miles an hour. It also saves the expence of attendance and coals, which is very considerable at upcast shafts."

A different method has been proposed by Dr Trotter, for destroying the fire damp or inflammable air of mines*. This is by fumigation, which is conducted in the same way as that which has been recommended in destroying contagion and exhalations. The utensils required for this purpose are small flat stone dishes, made thick, and about 2 inches deep, with a glass funnel for introducing the acid which is employed. The ingredients are common salt, the purer it is the better; oxide of manganese, and concentrated sulphuric acid, or, as it is denominated in common language, strongest oil of vitriol. The following are the proportions of the ingredients directed for one fumigation.

	Oz.	drs.	grs.
Common bay salt -	3	2	10
Black manganese, finely powdered	0	5	17
Water - -	1	2	33
Strong sulphuric acid -	1	7	50

The salt and manganese being pounded together, are put into the stone-ware dish, and the

* Proposals for destroying Fire and Choak-damps, Newcastle, 1805.

water is poured upon them. The sulphuric acid is then added slowly by means of a glass funnel. This quantity is said to be sufficient for a space of 16 feet by 12; but the author observes, that the repetition of the fumigation must depend on the manner in which the fire damp is evolved.

Where fire damp is confined in close situations, it is recommended by the same author to surround the spot with a number of vessels giving out the gas, and to open the door leading into it by slow degrees. The vessels are then to be carried nearer and nearer till the whole of the fire damp is consumed.

The chemical principle on which the process now recommended is accounted for, is, that the oxygen of the oxymuriatic acid gas being in a loose state of combination with the muriatic acid, separates from that acid, and combines with the hydrogen gas, or fire damp, and thus water is formed; but in consequence of the great quantity of heat which is evolved during the combination of the oxygen and hydrogen, the water is converted into steam, and does not appear under its more ordinary liquid form. This, says the author, is the whole secret of destroying hydrogenous gas, or fire damp.

Choak-damp (carbonic acid gas of chemists) is often extremely troublesome in coal mines, and not unfrequently proves fatal to the workmen employed in them. The method of dislodging choak-damp, recommended by the same author, is the following: Water about the temperature of 40° is found to dissolve equal parts of its bulk of the gas; but as the temperature of the water in a deep pit is commonly above 50°, it will not combine with more than two thirds of its bulk. To effect this combination with water, the common fire engine, which is employed in extinguishing fire, is proposed. The mouth of the tube is to be directed to the spot where the choak-damp is collected, and such a quantity of the water is thrown in as to take up the whole. For the purpose of diffusing the water more speedily, it is proposed to fit up the tube in the manner of a garden watering pot, so as to sprinkle and break the liquid into the form of a shower. It is also suggested that quicklime, which has a powerful affinity for carbonic acid, or choak-damp, being mixed with the water, would still more effectually promote its absorption.

Coal of Staffordshire.—The great abundance of coal, iron-stone, limestone, and clay, which this county affords, together with the intercourse which has been formed by means of canals between the distant parts of the kingdom, and particularly with the sea-port towns of Bristol, Liverpool, and Hull, has promoted the establishment of iron founderies, forges, and furnaces, and an immense variety of other extensive manufactories; and hence employment is given to a multitude of workmen, in forging various kinds of goods, as guns, locks, screws, and nails; of the latter of which, namely nails, the quantity manufactured in this district is supposed to be greater than in any other in the world. To the great abundance of the valuable materials now noticed, the towns of Birmingham, Dudley, Wolverhampton, Stourbridge, and others, owe their foundation and prosperity.

The tract of country, says Mr Keir *, from whom this account is taken, most worthy of attention, is that which is distinguished by a bed of coal of 10 yards thick, and within the reach of human industry and practical advantage. This tract is about 7 miles in length, and on an average about 4 miles in breadth. Beside this valuable tract of coal, there are other thinner beds of 3 or 4 feet thick, which extend northwards over a space equal to the thick bed of coal. The thin seams begin at the distance of a few miles from the place where the ten yard seam crops out; the latter has been traced no farther in that direction, and Mr Keir supposes that the thin strata rise from under the 10 yard bed.

The coal district of this country is characterised by certain prominent features. A range of limestone mountains rises on the northern tract, near Wolverhampton and Bilstone, and extends south to Dudley, which lies on the slope of the last chain

* Monthly Magazine, vol. xxviii. p. 35.

of mountains. Opposite to the limestone hills another range of mountains rises from the side of Dudley, and proceeds nearly in the same direction, but a little more to the east. This forms another striking feature. This range of mountains proceeds from Dudley through Rowley; hence they are called Rowley hills; they divide afterwards into two branches, and terminate in a valley between Old Bury and Hales-Owen. The latter range of mountains is composed of basaltic rock, which produces a marked distinction between it and the former. Beside these two ranges, there are two detached hills, which have an influence on the inclination of the coal. On the one stands the church of Wednesbury, and the other is near the village of Netherton.

The inclination of the coal in this district corresponds with that of the limestone strata. The range of mountains from Dudley to Wolverhampton consists of beds of limestone, which are so considerably elevated on each side, that they form a long ridge near their tops, not unlike the roof of a house. In the same manner, the coal and its accompanying strata, on the east and west of these mountains, have the same inclination as the neighbouring limestone strata. And to show how much this correspondence is preserved, as the west side of the range of limestone hills is steeper than the east side, the coal on the west side is more inclined, and is sooner out of the reach of mining operations than the coal on the east, where the principal coaleries are established. Farther, as the limestone hill at the northern extremity of the range corresponds only with the general formation of the other hills on the east side only, the coal is also only found on that side.

From the fact, that the bed of coal in this district is not extended over the limestone hills, the author infers, that it has been broken off near their base, and skirting the eastern and western sides. In some places its termination appears above ground, but is generally covered with earth. As this termination, the author farther observes, is not by gradual diminution, but abrupt, and at once like a fracture, we cannot, from this circumstance, and from the corresponding inclination of the coal and limestone strata, avoid inferring, that the same convulsion which broke through and raised the strata of limestone into the form of mountains, must have also broken and raised the superincumbent strata, of which coal is one; and that these strata being softer than the rock, were thrown off, or, having been shattered, have long since been washed away with the floods, so that now no vestige remains of this convulsion upon the hills but the solid ribs of limestone which form the mountains, and which have been able to resist the action of the air and water.

The above remarks, whether we coincide in the opinion of the author in considering the relative position of the coal strata and limestone, as the effect of a dislocation, afford another proof in confirmation of the general fact already stated, of limestone forming the boundary of coal. As the coal in approaching the detached hills of Wednesbury and Netherton preserves the same inclination as the strata of those hills, it is concluded that the coal is cut off, and that the hills are composed of limestone; but as the coal approaches to the range of the Rowley or basaltic hills, it has been ascertained that it does not crop out there; but on the contrary, as it is found at the foot of these hills, at moderate depths, and on both sides of the range, it is supposed that the stratum passes under them. This seems to be a very probable circumstance.

Some varieties of the coal of this county afford beautiful specimens of iridescent coal, or, as it is called, *Peacock Coal*, from the variety of colours exhibited on its surface, in consequence of the thin laminæ producing a refraction of different rays of light.

Coal of Derbyshire.—This county, and particularly in the eastern and north-eastern parts of it, contains numerous excellent beds of coal. The nature and thickness of the strata which accompany the coal, as well as the thickness of the different beds of coal itself, will be seen by consulting Table III. in the foregoing section. The enumeration of the strata in that table is taken from what was observed in sinking a pit in the eastern part of the county. It has been remarked of the strata accompanying the coal in this county, that although a general resemblance is observed, yet they are various and uncertain in quality, thickness, and relative position, in different situations; and even in places not far distant from each other, there seems to be no correspondence in the order of their distribution. The above remark shows that the coal strata of this county do not preserve any great degree of uniformity and regularity; and indeed the same remark is not inapplicable to most other coal districts of the kingdom. It may be added, that a proper degree of attention to this circumstance would, in many cases, be of great practical utility, by saving an immense load of expence, which has often been incurred in sinking pits and establishing coaleries, in the expectation that the strata would continue equally uniform and regular as they have been found in places in the vicinity.

In the eastern part of the county, the inclination of the coal strata is generally to the east, and particularly where they join the gritstone and the limestone. From this latter circumstance, it would appear that limestone also forms the boundary of the coal district in this county. On the western side of the coal district where the gritstone appears, it is stated that the coal strata generally decline from it, although in some situations, it is said that they dip under the gritstone. But it may be noticed in general, that the inclination of the coal strata is greatly affected by numerous faults or dislocations which are met with in this county; and as they have been discovered in many places, and extend in almost every direction, the inclination of the strata is very different in different situations.

A peculiar position of the strata has been observed at Chesterfield and Heanor in this county. They dip for a considerable space towards one common centre, and by this disposition form a kind of basin or deep circular figure. In the southern part of the county, there are two small coal districts from which coal has been obtained; the one is situated at Newhall, and the other at Measham. At Newhall the strata decline chiefly to the south; but they dip also from the north, east, and west, towards one common point. The coal has been found cropping out at Newhall park, to the west, about 500 yards from Brislincote-hall to the north, and to the east near Swadlincote, at a small distance from the turnpike road which lies between Ashby and Burton. The extent of ground which is included in this coal district is about half a mile from the place where the coal crops out on the north to its most southern dip; and the places where it crops out on the east and west are about a mile distant from each other.

The other coal district noticed above is at Measham, and the portion of the strata is the reverse of the former; for they dip from the south, east, and west, towards one common point. The crop edge of the coal is seen on the west side, beyond the village of Oakerthorpe, on the east side near to Wilsley, and on the south side about the distance of half a mile from Swebstone.

Coal is found also at Chinley hills near Chapel-de-Frith, and the strata are observed to dip in opposite directions on the different sides of the hill. In that part which contains coal the inclination is to the west, and on the opposite side it follows the declination of the hill to the east. Coal has been discovered also to the south-west of Buxton; and it is supposed that the strata incline to the west, and that the coal is at no great depth.

The thickness of the beds of coal which have been wrought in this county is from 2 feet to 5, 6, 7, and even 10 feet, as at Newhall; and the lowest of these is found at the depth of from 35 to 40 fathoms *.

It appears from a grant which was made by Thomas de Chaworth, lord of Alfreton, to the monks of Beauchief abbey, that coal was wrought in Derbyshire so early as the reign of Edward II. for by this grant permission was given to the

* Pilkington's View of Derbyshire, vol. i. p. 81—92.

monks to supply themselves with that mineral in any quantity they thought proper, from the liberties of Norton and Alfreton.

Coal of Gloucestershire.—From the description which is given of the coal of this county, it appears that it is also bounded by a range of limestone rocks. These rocks begin at Cromhall, and, expanding on each side, meet again in Somersetshire, thus giving to the district which they include an elliptical form. Coal is found every where within this district, but it is most abundant, and most accessible in the forests of Dean and Kingswood; from the latter of which the consumpt of the city and neighbourhood of Bristol, both for domestic and manufacturing purposes, derives its chief supply. Not fewer than 120 pits are wrought in the forest of Dean; and in the parish of Westerleigh, particularly at Coal-pit Heath, very extensive operations in the coal mines are carried on.

The inclination of the strata of coal of this county is to the east, and it dips about 1 foot in 25. The beds of coal vary in thickness from 2 to 5 feet; the depth of the pits is generally from 30 to 40 fathoms, and the deepest do not exceed 60 fathoms. The coal, it is said, has not been wrought to a greater depth, as the usual methods of freeing coal mines from water by means of machinery, and particularly by the improved steam engine, are scarcely known in this part of the country *.

Coal of Shropshire.—According to the mineralogical sketch † of Shropshire, from which the following account of the coal is taken, that county admits of a natural division into the flat and the hilly, which is pretty distinctly marked by the course of the river Severn. The northern part of the county, from the Severn at Shrewsbury to the confines of Cheshire in the north, and from Drayton on the borders of Staffordshire in the east, towards Oswestray on the borders of Wales on the west, it is flat, varied only by gentle swells, and here and there some naked rocks; but on the other side of the Severn from Shrewsbury to Ludlow on the south, and from Bridge-north on the east to the borders of Montgomery on the west, it presents a mountainous aspect. The prevailing rocks in the flat district are composed of sandstone, which appears on the surface in different places. A range of limestone rocks begins at Llanymynich, near the confines of Montgomeryshire; the strata rise towards the Welch mountains, and in some places to a considerable height. At Oswestry the country rises towards the north-

* Beauties of England, v. p. 518. Rudge's Gloucestershire, vol. ii.

† Townson's Tracts in Natural History, p. 158.

west, and near it there is a coarse grained sandstone, different from that found in the flat country, and reposing on limestone, which latter forms a precipitous range of rocks, facing the Welch hills on the north-west. Two or three miles to the south-west are situated the coaleries of Llwynymain and some others, the strata of which are supposed to rest on the above coarse grained sandstone; and it is observed that the argillaceous and sandstone strata which accompany the coal, are marked with numerous vegetable impressions.

The wrekin, which seems to be composed of green-stone, sandstone, and a rock having the appearance of a breccia, is about 10 miles from Shrewsbury, and rises from the plain near the banks of the Severn, forming a ridge of two miles in length, in a north-east and south-west direction. On the east side of this mountain lies the coal district of Coalbrook Dale. This district is about 8 miles long and 2 broad, and runs in a north-east and south-west direction nearly parallel with the mountain. The whole of this district is considerably above the level of the plain of Shropshire; but the southern part of it is, in some places, not less than 500 feet higher than the surface of the Severn. The inclination of the strata is various. In some places it dips to the east, and in others to the south and south-west, about 1 yard in 10. The coal of this district, with its concomitant strata, reposes on dye earth and basalt. The former is on the east side, and the latter on the west. The dye earth is a stratified mass, which in the neighbourhood of Coalbrook Dale is at least 100 yards thick, and contains petrifactions of shells. It is composed of more than one half of argillaceous earth, above one fourth of lime, and a smaller proportion of siliceous earth; but in other places, it would appear that the coal strata are supported by limestone.

The coal of this district is wrought to the depth of 90 fathoms, and no fewer than 15 or 16 beds of coal, from a few inches to 6 feet in thickness, have been discovered in this depth. In the enumeration of the strata included in the depth now mentioned, the lowest bed of coal, called the little flint coal, is 2 feet thick, and lies on a fine grained white sandstone, which is from 10 to 45 feet in thickness. This latter is succeeded by the dye earth, basalt, or limestone.

But the coal district of this part of the county does not preserve the same degree of uniformity through its whole extent. In several places the strata have undergone considerable dislocations; and in particular two of these, which run nearly north-east and south-west, have deranged the strata, and produced a depression on the east and west sides, by which the corresponding strata are from 100 to 200 yards lower than in the middle. The elevated middle district, which, however, does not appear on the surface, is above 7 miles long, and varies fron 1 to 2 miles in breadth, presenting the greatest facility when working the mines, affords the greatest abundance of coal and iron-stone. The depression of the strata is locally denominated a *swamp*. Beside the principal dislocations now noticed, there are some disturbances in the middle district, which have produced depressions of the strata to the extent of 50 or 60 yards. In the district of Coalbrook Dale, it is said, 260,000 tons of coal are raised annually.

But coal is found also in other parts of Shropshire. Near Darnford, a very small vein of coal was discovered, which, the author observes, is really a vein, and not a thin bed or stratum *. It was scarcely an inch thick. This circumstance of the distribution of coal in veins was formerly noticed as a rare occurrence.

Eight or nine miles south of Shrewsbury, in a valley formed by the Longment, and the Lawley and Caradoc hills, coal has been wrought. This coal is accompanied by limestone, which is 4 or 5 feet thick, covered by 60 feet of argillaceous strata, and separated from the coal by 30 feet of the same kind of strata. The coal is about a yard thick, and it is said is chiefly employed for burning limestone; from which circumstance it may be inferred that it is of an inferior quality; and in-

* Townson's Tracts, p. 187.

deed this is most generally the case with all the coal in the vicinity of limestone.

In another part of this county, there are two coal districts, which are situated in the Brownclee hill and the Titterstonclee hill, the latter of which is 3 or 4 miles south from the former. They are flat topped hills, and are the highest in Shropshire. They are about 5 or 6 miles in length, and about 2 or 3 in breadth; both contain coal and iron-stone, which in both are in some parts covered by a thick bed of basalt, which forms two irregular and more elevated ridges than the other parts of the hill. The strata in both dip from the circumference to the centre; but in the Brownclee hill the strata are thin, while the principal bed of coal in the Titterston is 6 feet thick.

The Titterstonclee hill contains 6 different coal fields, which exhibit a considerable diversity in the extent and thickness of the strata. These different coal fields dip from the circumference to the centre of each, thus forming so many basins. The most extensive and valuable of these fields is called Cornbrook, and is about a mile in length, and half a mile in breadth. It is remarkable for having a thick bed of basalt, which lies above the coal.

In the following tables, the distribution, names, and thickness of the strata, in two different places of this field, will be seen.

Strata found in sinking the deep Pit in the Southern Part of the Hill.

	Yards.	Feet.
Earth and sandstone rock -	10	1½
Basalt, called Jew-stone -	64	1½
Sandstone, rock, bind, clunch, and coal roof. Dry clays - -	23	0
The great coal - -	2	0
Coal bottom and iron-stone. Dry clays	1	1
Iron-stone measure. A dry clay -	1	0½
Three quarter coal - -	0	1
Clumper. Hard dry clay -	2	0
Smith's coal - - -	1	2
Smith coal bottom. Dry clay to the four feet coal rock - -	0	2
	104	10

Strata in the Water Pit one Quarter of a Mile to the North-east of the former.

	Yards.	Feet.
Basalt - - -	48	0
Brown and white clunch. Dry clay	6	0
Red rock. A yellowish sandstone	9	0
Bind and clunch - -	9	0
Penny iron-stone measure. Dry clay	1	0
Clunch. Dry clay - -	3	0
Brown rock. A yellowish sandstone	6	0
Tuff (plastic clay) and sand -	1	0
Carry over	83	0

	Yards.	Feet.
Brought over	83	0
Black bind. A dry clay -	4	0
Black coarse sandstone -	5	0
Stong clay - -	1	0
Horse flesh earth. A variegated red and white marl - -	6	0
Gray sandstone - -	6	0
Bind. A dry clay - -	2	0
Great coal rock. A whitish sandstone	6	0
Coal roof. Dry clay -	3	0
Great coal - - -	2	0
Coal bottom, pounsin. A dry clay	1	0
Iron-stone roof and measure. A dry clay - - -	1	1
Three quarter coal and bass -	0	2
Clumper. A hard dry clay -	3	1
Smith's coal, and clod in it -	1	2
Strong clunch. Dry clay -	2	0
Flan and bass. Hard dry clay -	0	2
Strong clunch. Dry clay -	3	0
Four feet coal and bass -	1	0
Strong brown clunch. Dry clay	1	0
Sunk into the four feet coal rock	3	1
	134	9

The Newbury coal field at the south end of the hill is half a mile long by a quarter of a mile broad. The number of beds of coal is the same as in the preceding, but they are always about one third thicker. No basalt is found in this coal field; and in the other small fields in this hill, the basalt is also wanting, and the bed of coal is only from 18 to 30 inches in thickness. It has been conjectured that the basalt lies under the coal at the Hill Work coal field, which is one of the six in the Titterston Clee-hill. This coal field lies upon the Cornbrook coal field, or is surrounded by it; for when the coal of the latter is cut off by a fault in the neighbourhood of the former, the miners, in carrying on their operations in that direction, always meet with basalt.

Coal of South Wales.—The coal of South Wales is deposited in the form of a basin, in the counties of Monmouth, Glamorgan, Brecon, Caermarthen, and Pembroke. Of this coal an excellent description, equally remarkable for its perspicuity, precision, and brevity, has been drawn up by Mr Martin *. From this description the following account is extracted.

The coal strata now alluded to are deposited in a limestone basin, the length of which is upwards of 100 miles, and the average breadth in Pembrokeshire is from 3 to 5 miles only; but in the other counties which it traverses, the breadth is from 18 to 20 miles. The limestone which forms the boundary of this coal is seen on the surface in the counties of Monmouth, Glamorgan, Caer-

* Philosophical Transactions, 1806. p. 342.

marthen, and, in Mr Martin's opinion, no doubt can be entertained of its continuation from Newton across Swansea bay to the Mumbles, and from Llanmaddock hill across Caermarthen bay to Tenby. It appears also on the surface on the south side of the basin in Pembrokeshire, at Tenby, Ivy Tower, Cochelard, Bitchurch, Williamston, Lawrinny, and Johnston; and on the north side of the basin, in the same county, it is seen at Templeton, Picton, and Persfield. Mr Martin adds, that it certainly forms an underground connexion from point to point. The greatest portion of this mineral basin is situated in Glamorganshire; Monmouthshire includes the next in point of quantity; Caermarthenshire the next; Pembrokeshire the next, and Brecknockshire possesses the least of all. This will appear by inspecting the map, and tracing the outlines of the mineral basin, which is of an irregular elliptical form, and considerably protracted and narrowed to the west.

The northern boundary begins at Clydach, a little to the west of Abergavenny, and stretching through the forest of Brecon, passes by Cribbath, the Black mountain, Llanbidie; from which latter place it runs nearly in a south-west direction to Kidwelly, and from this it stretches in a westerly course across Caermarthen bay to Templeton, Picton, and Persfield, till it reaches St Bride's bay. The southern boundary may be traced from Pontypool by Risca, Llantrissent, Margam, across

Swansea bay to the Mumbles, and from thence to Llanmaddock hill, from which latter place it stretches across Caermarthen bay to Tenby, and continues its course by Ivy Tower, Williamston, Lawrinny, Johnston, &c. to St Bride's bay.

To form a distinct notion of the inclination of the strata in this district, an imaginary line may be drawn in an east and west direction through the middle of the basin; and on the north side of this line all the strata have a gradual ascent to the northward. On the south side of the line they rise to the southward till they reach the surface. The strata in the neighbourhood of Pontypool must be excepted from this general position, because there they rise to the eastward. From this account of the inclination of the strata, it is obvious that the depth of the different beds of coal from the surface must depend on their respective local situations. The deepest part of the basin is between Neath in Glamorganshire and Llanelly in Caermarthenshire; and here the extent of the upper stratum of coal is not more than a mile from north to south, and but a few miles in an east and west direction. Its greatest depth does not exceed 50 or 60 fathoms. The next stratum of coal, and those likewise beneath it, lie deeper, and extend farther, both in length and breadth, and the lowest, which are accompanied by parallel strata of iron ore, of the latter of which 16 have been discovered in some places, occupy the whole space between Llanmaddock hill, near the entrance of Burry river on the south side of the basin to Llanbidie; from the Mumbles to Cribbath; from Newton Down to Penderryn; from Castle Coch to Castle Morlais; and from Risca to Llangattock; and stretching in length on the south side of the basin from Pontypool through Risca, Llantrissent, Margam, and across Swansea bay to Llanmaddock hill; and on the north side through Blaenafon, Sirhowy, Aberdare, Llanbidie, and the Great mountain, to Pembrey hill near Llanelly in Caermarthenshire. The depths of these beds of coal, at the centre range of the strata, are from 600 to 700 fathoms.

The strata of coal which extend from Pembrey hill through the bay of Caermarthen and Pembrokeshire, are considered only as a continuation of the strata in the counties of Glamorgan and Caermarthen, which lie next to, and parallel with the north side of the basin, all the remaining strata rising southward; and the middle ranges on the north side of the basin are lost somewhere between the place where they meet the sea near Llanmaddock hill and the south side of Pembrey hill, in their course towards Pembrokeshire; in consequence, it is supposed, of the sides of the mineral basin being contracted, or rather by its becoming shallower; for it is observed, that in Pembrokeshire none of the strata of coal exceed 80 or 100 fathoms in depth, and consequently all those which do not lie more than 500 or 600 fathoms deep in Glamorganshire and Caermarthenshire have not reached this county; because, it is added, the depth and width of the basin have not been sufficient to hold them.

There is a very remarkable difference in the quality of the coal in different parts of the mineral basin. The strata of coal at the east end of the basin, extending from Pontypool to Blaenafon and Clydach, and from thence to Nanty Glo, Sirhowy, Tredegar, Romney, Penderryn, Cyfarthfa, Aberdare, and Hurwain furnaces and iron works, are of a coaking quality; but from the last mentioned place, the whole of the coal to St Bride's bay are of a different quality, and are known by the name of stone coal, or blind coal; I suppose from the use to which it is applied, the large being used for drying malt and hops, and the small for burning limestone. The strata of coal on the south side of the basin, extending from Pontypool through Risca, Llantrissent, to Llanelly and the south side of Pembrey hill, are chiefly of a bituminous and binding quality.

The beds of coal in Glamorganshire have not been wrought to a greater depth than about 80 fathoms; and here, as well as in Monmouthshire, the water is carried off by means of levels or horizontal drifts, the construction of which is greatly facilitated by the deep valleys, which generally run in a north and south direction, and thus traverse the range of the coal strata; so that this valuable mineral is accessible without the expence of deep pits and powerful machinery to carry off the water.

The regular course of the coal in this district is frequently deranged by knots, dykes, or faults. These irregularities are not limited to the edges of the strata, but take grand ranges through the interior of the basin, generally in a north and south direction; and often produce dislocations of the whole strata for hundreds of acres together, to the extent of 40, 60, 80, and even 100 fathoms. One of the most remarkable of these dislocations is seen at Cribbath, on the north side of the basin, where the strata of limestone are in an erect position; and there is another of very considerable magnitude between Ystradvellte and Penderryn, where all the strata on the north side of the basin are displaced many hundreds of yards to the southward. This dislocation is seen at Dinas.

This district contains 12 veins or beds of coal, which are from 3 to 9 feet thick. All these beds taken together amount to 70½ feet of coal. Beside these, there are 11 more from 18 inches to 3 feet, which taken together make 24¼ feet, and added to the former, make the whole thickness of the coal in the district 95 feet; and beside these, there are some smaller veins from 6 to 18 inches in thickness, which are not included in the calculation. The average length and breadth of the mineral district now described being taken, the extent will be found to be about 1000 square miles, containing 95 feet of coal in 23 distinct strata, and these will produce, in the ordinary way of working 100,000 tons per acre, or 64,000,000 tons per square mile.

Bovey Coal.—This coal, which is met with in an extensive flat called Bovey Heathfield, near Exeter in Devonshire, from which it derives its name, affords an excellent example of the existence of that mineral in alluvial land. The Bovey coal, it may be observed, is the compact carbonated wood of Kirwan, and the common brown coal of other mineralogists. The flat in which this coal is found, is supposed to be lower than the level of the sea, for it seems to have been formerly covered by the tide. The strata of coal extend 9 miles to the southward, running through the Heathfield by Newton marches to Abbots Kerswell. They generally lie to the west of the beds of potter's clay, which are distributed through various parts of the Heathfield; and sometimes the strata of coal traverse the beds of clay. The uppermost stratum of coal comes within a foot of the surface, and is only covered by a bed of whitish sand intermixed with clay. The inclination of this stratum is to the south. It dips about 20 inches in a fathom. The whole depth of the strata of coal hitherto discovered, and including the beds of clay with which they alternate, is about 70 feet. The thickness of the strata of coal near the surface is from 18 inches to 4 feet, and they are separated from each other by beds of a brownish clay, which latter are nearly of the same thickness; but they diminish in going downward, while the beds of coal become thicker in proportion. It is observed too, that both the clay and the coal become more compact and solid as they become deeper. The deepest bed of coal is 16 feet thick. It reposes on a bed of clay, which is succeeded by a sharp green sand, not unlike sea sand, 17 feet thick. From the thick bed of sand there issues a warm spring of water, of a greenish colour, which is said to be impregnated with sulphur and vitriol (copperas or sulphate of iron). Some of the beds of clay with which the beds of coal alternate, contain thin seams of the same mineral. The coal which is dug out for the purposes of fuel, is obtained from an extensive open mine at the west end of South Bovey town. The descent to this mine is so easy, that horses are employed to bring up the produce.

The different beds of the Bovey coal exhibit a general resemblance in their substance and quality; but at the same time there is some diversity in colour, form, and texture, of the different veins. That part of the coal which is in contact with the clay is of a dark brown colour, and appears like a mass of coal and earth mixed. Others are of a laminated texture, the laminæ running in an oblique and undulating manner, and having a strong resemblance to the roots of trees. Other beds of this coal, particularly those in the centre of the strata, and in the lowest and thickest bed, are of a black colour, and almost as heavy as pit coal. They are more easily divisible into laminæ, and are more strongly impregnated with bitumen. They are distinguished by the name of stone coal, and produce a stronger and more durable fire than that obtained from the other beds.

The bed of coal called wood coal, is considered as the most remarkable of all the strata in this place. It is sometimes of a chocolate colour, and sometimes of a shining black. The former seems to be less impregnated with bitumen, is less compact and heavy, and has more the appearance of wood than the latter. It lies in straight and even veins, and is sometimes dug out in pieces of three or four feet long. Other pieces of the same kind are found lying upon them in all directions, and without any mixture of earth, or any interstice, excepting some small crevices, by which the pieces are divided from each other. This mineral is composed of a number of laminæ or thin plates, lying horizontally upon each other, and sometimes having small protuberances like the knots of trees. Pieces of spar are sometimes found in the middle of this coal. When the coal is first dug out, and before it is deprived of its moisture, the thin pieces of which it is composed divide like horn; but when it is dried, it loses its elasticity, and becomes short and crisp. It is easily separated into thin laminæ or splinters, especially after being exposed to the heat of the sun, which, like the fire, makes it crackle, separate, and fall to pieces *.

Various speculations have been entertained with regard to the origin of what is usually denominated wood coal. The Bovey coal is generally supposed to be derived from great numbers of trees which have in various distant ages been washed down by torrents from the neighbouring hills, and on which the alternating beds of clay have from time to time been deposited. The situation of the Heathfield, in which the Bovey coal lies, seems to confirm this opinion, as it was probably at some period a morass, and is almost surrounded by the range of hills that lie at the feet of Dartmoor and Haldon. The lightness and appearance of the wood coal are also regarded as circumstances favourable to this opinion, as well as the laminæ being disposed in all directions; which seem to show that the coal is formed of trees, thrown together in a confused manner across each other. The resemblance of this coal to the surturbrand of Iceland, and the piligno of Italy, which are pretty generally believed to be

* Polwhele's History of Devonshire, vol. i.

fossil wood, is quoted as another proof of its vegetable origin.

On the production of coal from morasses, Dr Darwin observes, "that it is evinced from the vegetable matters frequently found in them, and in the strata over them, as fern leaves on nodules of iron ore, and from the bog shells or fresh water muscles sometimes found over them; of both which I have what I believe to be specimens; and is further proved from some parts of these beds being only partially transformed to coal, and the other part still retaining, not only the form, but some of the properties of wood; specimens of which are not unfrequent in the cabinets of the curious, procured from Loch Neagh in Ireland, from Bovey near Exeter, and other places, and from a famous cavern called the Temple of the Devil, near the town of Altorf in Franconia, at the foot of a mountain covered with pine and savine, in which are found large coals resembling trees of ebony*."

The particular species of wood of which the Bovey coal is formed is supposed to be the pine; and it is said that a specimen with the bark remaining has been found, which indisputably belongs to this kind of tree. But another circumstance observed by Mr Pering is adduced in favour of this opinion. On examining the appear-

* Botanic Garden, Note 23.

ance of the ground about 100 yards from the pits, and which is just on a level with the Heathfield, he observed numerous stumps of trees, which appeared to have formerly belonged to bodies of immense size. These trees were in their natural position, and fixed in the ground by means of their roots. They were much jagged in appearance, and exhibited no marks of the saw, but were evidently cut with the ax; in colour, lightness, and texture, they bear a close resemblance to deal, from which Mr Pering infers, that the species of tree from which the coal was derived was probably the pinus sylvestris, or Scotch fir *.

Coal of Scotland.—The extent of the coal districts of Scotland is still more limited than those of England, and affords another proof of the remark already made, with regard to the partial distribution of the strata of coal. If a line be drawn from the mouth of the Tay on the east coast, by Stirling, to the north end of the island of Arran on the west coast; and if another line be drawn from St Abb's Head on the east coast, to Girvan in Ayrshire, on the west coast, almost the whole of the coal of Scotland will be included within these lines, which are nearly parallel to each other. The only exceptions of importance are the coal districts of Sanquhar, on the banks of

* Beauties of England, iv. p. 37.

the Nith, and Cannoby on the banks of the Esk in Dumfries-shire. It is true, that a small quantity of coal has been dug out near Portree in the isle of Skye, and some appearances have been observed in the isle of Mull; and attempts, which were attended with very considerable expence, have been made to discover that valuable mineral in the county of Sutherland: but none of the investigations which were carried on in the search for coal have been successful in any of these places, or, considering the nature of the strata, afford any ground of hope that it exists in sufficient extent and thickness to defray the expence of the operations with which it must necessarily be attended.

It is not, however, to be understood, that coal exists in every part of the space included within the limits now described. Some of the coal districts within the general boundary are of considerable extent, while others are confined within a very limited spot, and a very large proportion of the whole space is entirely destitute of coal.

The extensive coal field which lies to the south and east of Edinburgh forms the boundary of the coal district of Scotland, on the east coast and on the south side of the Forth. The peculiar position of the strata in different parts of this coal field admits of a very natural division, which has been accordingly adopted in describing them. The strata in the immediate vicinity of Edinburgh, to the southward and eastward, that is, in the north-west division of the field, dip to the south-east at an angle, which varies from forty-five to forty-seven degrees, and even in some places they are nearly perpendicular. But in the south-east division the strata are almost in a horizontal position, or have only a very gentle inclination, especially at the extreme boundary of the field, to the north-west. The divisions now noticed are distinguished by the names of the *Edge* coal seams and the *Flat* seams.

The flat division is bounded on the south-east by red sandstone and limestone. A very large mass of the former is seen on the south-west of the village of Salton, and has an inclination about north and by west. In the immediate vicinity of the same village, and on the east side, there is a great body of a bluish coloured limestone. This limestone is covered with a stratum of soft sandstone, which is succeeded by a thin stratum of bituminous shale or blaes, reposing immediately on a bed of limestone from 15 to 18 feet thick. A stratum of coal about 12 or 15 inches in thickness lies under the limestone. Approaching nearer to the coal field, another great body of limestone is seen at the bridge of Salton; where, as well as at the village of Salton, a great quantity of this stone has been dug out for the purposes of manure. The strata of the latter place, which is called Spilmersford, and is on the estate of Pencaitland, are nearly the same as at Salton; the inclination or dip which is to the north by west, is also nearly the same; but the coal which succeeds the thick bed of limestone is 18 inches thick. The coal which lies under the limestone is of a very inferior quality, as is usually the case with coal in such situations; and even if it were sufficiently thick to admit of working, it would scarcely answer the purposes of fuel.

The first field from which coal is dug out near this boundary of the coal district is about a mile and a half to the north-west of the Spilmersford limestone quarry, and is also on the estate of Pencaitland. The strata in this field have nearly the same inclination as those of the limestone described above. The first seam, or bed of coal, which is from four to five feet thick, is covered by a thick bed of beautiful white sandstone, whose thickness is from 13 to 14 fathoms. About 6 or 7 fathoms deeper than the first seam, another bed of coal is met with, which is only from 20 to 30 inches thick. This is supposed to be the same bed of coal as that which is seen at the bottom of the limestone rock at Spilmersford. But if this be the case, the limestone must be cut off, while the stratum of coal is continued; for the limestone has not appeared in any of the workings in the coal-field at Pencaitland.

The regularity of the strata in this field is greatly disturbed by various dislocations, and particularly by numerous depressions of the strata, thus producing small basons, in which the strata dip from the circumference to the centre, and thus increasing the difficulty of carrying off the water and working the coal.

The coal is wrought to a considerable extent at Ormistoun, to the westward of Pencaitland, and to the north of the latter place, on both sides of the ridge on which the village of Tranent is situated. The same coal is continued till it is cut off by a powerful whin dyke, which appears near Johnshaven to the westward of Prestonpans. This dyke, which forms a natural pier at Johnshaven, stretches away to the eastward, and is seen traversing the limestone strata near the village of Linton, between Haddington and Dunbar. No coal has been wrought on the north side of this dyke; and although indications of coal are not wanting in several places along the shore, yet they are not of such a nature as to encourage the proprietors to undertake any expensive operations with the view of improving the discovery; and, indeed, I am persuaded, from any examination of the rocks which I have had an opportunity of making, that there is no accessible seam of coal which promises to defray the expence of working on that side of the dyke.

The precise spot where the flat and edge seams and their accompanying strata approach each other, is seen on the surface only in a very few places. The place of junction, on the shore, is about a mile west of Musselburgh. Between Mavisbank and Polton paper mill, on the banks of the North Esk, the flat strata are seen distinctly in the bed of the river, running towards the edge seams on the north bank, near the place from which the level that drains the Loanhead coal field passes out. At a little distance higher up the river, on the left side of the road which leads from Springfield Mill to Loanhead, and on the banks of a small rivulet called Bullstone, which runs into the Esk, there is a peculiar derangement of the strata, which is denominated a saddle. The whole of the strata of sandstone and ironstone, which are visible on the bank, rise from the north-west pretty rapidly, and then are thrown down to the south-east, at an angle of 47 or 48 degrees, which is the usual position of the edge coal strata. But by far the most distinct view of the junction of the strata, accompanying the flat and edge seams, is to be seen nearly at the extreme boundary of the coal field. The place alluded to is at the Esk paper mill on the banks of the same river, near Pennycuick. At that place a fine section of the strata in both positions is exhibited; from which it appears, that the junction takes place without the slightest disturbance either of the horizontal or the vertical strata. The latter circumstance is noticed, in consequence of an opinion which I find is held by some, that the junction of the flat and edge coal strata is marked by a considerable derangement. Another opinion, with regard to the distribution of the same strata, may be here mentioned. It is supposed that the edge seams on the north-west of this coal field are continued under the flat seams, and rise again towards the surface, on the eastern boundary of the district, as at Pencaitland. The only reason which I have heard alleged in support of this opinion is the supposed similarity in the nature and properties of the coal. But I suspect that a more accurate comparison will not show so near a coincidence in the qualities of the coal in the extreme limits of the field alluded to, as to give much countenance to an opinion otherwise so feebly supported.

After the full account of the coal district round Edinburgh, given by the author *, it would be unnecessary repetition to enter further into the detail of its natural history. It may, however, be added, that a new series of strata commences on the north-west boundary, the distribution of which is distinctly seen on the bank of the Water of Leith, a little below Slateford bridge, about two miles along the Lanark road from Edinburgh; it is seen also in a quarry at Craiglockhart, belonging to Dr Monro, and appeared in some unsuccesful at-

* Vol. I. chap. viii.

tempts in searching for coal on the same property. The strata have an inclination to the north-west, and dip at an angle of 45°. The seams of coal which appear in the section of the strata, on the bank of the river and in the quarry, are not of sufficient thickness to admit of being wrought with profit; and, indeed, hold out very little encouragement to have prosecuted the search, as was the case two years ago, at any great expence. Farther to the westward, and not much more than a mile distant, the character of the strata experiences another change. Here a great body of sandstone is deposited; and a fine section of the strata is seen at Hailes, the quarry of which has been long celebrated for furnishing stones to many of the splendid edifices which adorn the streets and squares of the modern part of Edinburgh. The strata dip with a moderate inclination to the east, and in the quarry exhibit a mass of sandstone fifty feet thick. This is succeeded by limestone of a very inferior quality, which, it is said, contains animal remains.

About 10 miles from Edinburgh, on the Glasgow road by Mid-Calder, an immense body of limestone appears, which is wrought to a great extent. Some indications of coal are visible in the banks of the river which passes the village of Mid-Calder; but, as is usually the case in the vicinity of limestone, it is not of sufficient thickness for working. A few miles farther to the westward, and not far from the road between West-Calder and Wilsontown, there is another great deposition of limestone, in the vicinity of which coal is wrought; but it is scarcely fit for any other purpose than burning the limestone.

At Wilsontown a regular series of coal strata commences, and continues, with the usual interruptions to be expected in extensive coal districts, to the neighbourhood of Glasgow. The Forth and the Clyde may be considered as the boundaries of this district on the north and south. A line drawn from Wilsontown through Whitburn, and another a little to the westward of Glasgow, both in a direction between south and north, may be taken as its limits on the east and west. After passing Blantyre, it ought to be noticed, the southern boundary must be carried across the Clyde, and extended to the Cathkin hills, a ridge of considerable elevation, on the northern declivity of which the mansion house of Castlemilk appears in a conspicuous situation.

But if we return to the northern boundary of the general coal district of Scotland, we shall find a great body of coal deposited on its eastern extremity. In this part of the district, as at Dysart, very extensive operations have been carried on, from the earliest period that mineral coal came into use as fuel in this country. The beds of coal discovered at Dysart, as well as the accompanying strata, have been already enumerated in Table IV.

of the preceding section. The coal strata continue to skirt the northern shore of the Forth from Dysart to Alloa, and occasionally stretch to a considerable distance into the interior of the country. But, in this extensive range, it must not be supposed that the continuation and regularity of the strata suffer no interruption ; on the contrary, they are not only subject to very great derangement from various dislocations, but there are also wide spaces, in which the coal is either entirely cut off by immense masses of limestone, or great beds of sandstone, or is so reduced in the thickness of the seams and in quality, as to be unfit for working or fuel.

The great abundance of coal and ironstone, which prevails in the districts now described, has given birth to numerous manufactures ; and in particular to the operations of the smelting furnace in the reduction of the ores of iron, as well as of converting that invaluable metal into the multifarious utensils and articles of machinery, for which the peculiar properties which it possesses, in its various states of combination, render it eminently useful. To verify the remark now made, the iron-works at Wilsontown, Shotts, Cleland, Airdrie, and Clyde ; but particularly the grand establishment of the same kind at Carron, need only be mentioned.

The coal district, after passing Glasgow, stretches westward on the south side of the Clyde, and occupies the valley or flat country, which has been marked out as the line of the Ardrossan and Glasgow canal. This tract, which is not very broad in any part of it, extends through Renfrewshire, and reaches to Dalry in Ayrshire. At this latter place the coal strata are interrupted, probably by masses of limestone or sandstone, some of which are seen at no great distance; and the coal does not make its appearance in sufficient extent and thickness to render the working profitable, till we reach the banks of the Garnock, after that river has passed Kilwinning. The coal has been long wrought on both sides of the river, almost to its junction with the sea below Irvine, but particularly in an extensive flat lying on the south side of the village of Stevenston, and stretching from Saltcoats, nearly three miles up the country, to the eastward. This coal field, the greater part of which is on the estate of Ardeer, belonging to Mr Warner, has yielded, for many years past, an immense quantity of excellent coal, the chief consumpt of which is the exportation to Ireland.

Excepting on the banks of the river Irvine, at a short distance above the town of the same name, and in the vicinity of Kilmarnock, not far from the banks of the same river, and also to the eastward in the same tract of country, in which places there are many excellent seams of coal, that valuable mineral has not been discovered, till, proceeding nearly 10 miles to the southward, it makes its appearance near the town of Ayr. The flat which extends from the banks of the river, and for more than a mile along the shore to the northward, and stretches to the eastward to the distance of about two miles, contains a great body of coal, which has been long dug out, not only for home consumption, but also for exportation to Ireland. From this point the tract of coal country stretches to the eastward, keeping at no great distance from the banks of the river Ayr, or of its tributary streams. In this tract are included the coal field of Mr Smith of Drongan; the coal in the vicinity of the village of Cumnock, and that of Muirkirk, near the head of the county of Ayr, where iron works have been established on account of the abundant supply of coal and ironstone.

From the banks of the Ayr to the banks of the Girvan, a distance of not less than 15 or 16 miles, the coal strata seem to be entirely cut off. The intervening rocks, in some of which appearances of lead ore have been discovered, as at Brown Carrick hill, an elevated ridge to the southward of Ayr, where trials have been made, but hitherto, I believe, with no great success, afford no indications of coal whatever; but on the north side of the water of Girvan, and on the property of Mr Kennedy of Dunure, a great body of coal is deposited. In this field there is a mass of coal in two or three seams, equal to 40 feet in thickness. The inclination or dip is to the southward, at a considerable angle. This coal is cut off before it reaches the sea to the westward by limestone and red sandstone.

There are no appearances of coal strata to the southward till we reach England; and the only other coal fields in Scotland, not included in the brief sketch now given, are Sanquhar and Cannoby in Dumfries-shire, a field belonging to the earl of Hyndford, and lord Douglas in Lanarkshire, and a small patch on the west side of the Mull of Cantire in Argyleshire. Some indications of coal have been met with in the island of Arran, as well as in the islands of Mull and Skye, and in the county of Sutherland already mentioned; but they seem not worthy of farther notice, as they afford no hope of profit to the proprietors, or advantage to the country.

I shall now conclude what has been said of the coal of Scotland, which is to be considered merely as an outline, with a short account of three coal fields which are distinguished by some peculiarities. The fields alluded to are Hurlet and Quarrelton near Paisley, the former remarkable for affording materials for an extensive alum-work, and the latter exhibiting one of the most singular masses of coal in the world; and Ricarton near Kilmarnock, containing the most extensive bed of blind coal in the kingdom.

Coal field of Hurlet.—This coal-work is situated about 3 miles south-east from Paisley, on the estate of the earl of Glasgow. It has been wrought, it is said, for three centuries. The bed of coal is about 5 feet thick, at the depth of 30 fathoms, and is covered by a bed of limestone, which is generally about 3 feet thick. The coal, as is usually the case in the immediate vicinity of limestone, is of a very inferior quality for the purposes of fuel, for it is strongly impregnated with iron pyrites; but on this very circumstance the chief value of these mines, as some of the materials which they afford are otherwise applied, depends. The extent of the excavation, excepting one fourth which has been left for pillars, is about a mile in length, and not much less in breadth. Between the stratum of coal and limestone there is a stratum of aluminous schistus about ten inches thick; and this schistus being exposed to the action of the atmospheric air, is in a state of gradual decomposition through the whole extent of the cavity, in the progress of which it flakes off, and falls down on the floor of the mine, where the decomposition still going on, causes the mass to swell up, and converts it into a light spicular efflorescence, to the height of 3, 4, and even the whole 5 feet of the excavation. Almost the whole of the 10 inches of roof is now converted into a native alum. The chemical reader, by considering the nature of the materials found in these mines, will be at no loss to account for the change which is thus produced. The pyrites of the coal is decomposed, and the sulphur being oxygenated, is converted into sulphuric acid, part of which combines with the oxide of iron, and thus forms sulphate of iron or copperas; while another part of the sulphuric acid combines with the alumina of the schistus, and probably also with an alkali, thus yielding a native alum.

A very singular combination of circumstances has favoured the production of alum in this mine. If the aluminous schistus had been disposed on the floor instead of the roof, the oxygenation of the surface only could have been effected, because the inferior portion would have been covered, and the process entirely interrupted. If the operations in working the coal had been begun at the lower part of the field, the waters accumulated at the lower part would have dissolved the efflorescence as it was formed; or if the workings had been abandoned at shorter periods, or if the length of time had been less, or the extent of surface more limited, the slow process of efflorescence would not have afforded a sufficient supply; or if a greater number of pits than usual had not been left uncovered, the diminished circulation of air would have greatly retarded the progress of the various changes.

Four different states of the aluminous schistus have been described. 1. In the first, the native material which forms the roof the coal, which, as already noticed, is 10 inches thick, is of a dense texture, with a conchoidal fracture. 2. In the first stage of its decomposition, it appears externally of a dirty light brown, with efflorescence, and numerous small cracks throughout, showing the slaty texture. 3. In the third state it is more completely separated; many of the parts have flaked off, and a white saline covering of efflorescence and saline matter in the cracks evidently forcing them asunder. This saline matter has a rough and ferruginous taste, and the filaments have a slight, woolly, or silky appearance. 4. In the fourth state, it is in the form of a light white, or pale greenish white mass, which consists of the silky or fine fibrous salt, intermixed with flakey fragments of part of the schistus which is yet undecomposed. In some places of the mass of saline matter, there is a considerable proportion of sulphate of iron or copperas, which gives it a greener colour: and in some parts of the mine, the saline matter is composed chiefly of sulphate of iron.

In consequence of the great abundance of materials afforded by these mines, an alum work was established about 12 years ago on a very large scale; and, indeed, is supposed to be the most extensive manufactory of the kind in Britain. It was begun by an enterprising company, Messrs M'Intosh, Knox, and Company, whose chemical knowledge has been very successfully applied in promoting the prosperity of this undertaking. A copperas work, but on a far more limited scale, has been established, for 40 years past, at the same place. I have thus far noticed the productions of these mines, not so much on account of their immediate connexion with the natural history of coal, as on account of the circumstances which seem to promote the changes which lead to the formation of the saline substances, which are the foundation of the valuable manufactories mentioned above; because, where circumstances are favourable, and many may occur, similar establishments may be projected. The period in which the changes take place in the production of native alum is, I believe, from 12 to 20 years.

Besides the mineral matters now described, two others are found occasionally in the same mines; the one I found, from a chemical examination soon after it was discovered, to be sulphate of magnesia. It was in the form of fine *spiculae*, some of which were about a foot in length, and of a fine white colour. It covered a space of 40 or 50 yards square, and had something of the appearance of a crop of corn. The other mineral alluded to, I found also by chemical analysis to be selenite, or sulphate of lime crystallized. It had been scarcely at all noticed when I visited these mines in the year 1797, and discovered it in the cavities of the limestone, and in the pavement of the mine, where it shot out in the indurated clay in the form of spicular crystals, crossing each other in all directions, and intermixed with small fragments of the clay.

Quarrelton Coal.—This coal field, which is situated in the county of Renfrew, is the property of George Houston, Esq. of Johnstone, and is perhaps the most singular mass of coal in the world. The whole extent of this coal field from north to south does not exceed a mile, and from east to west it is included within still narrower limits. To the north it crops out near the surface, and to the south it is cut off by whin rock. The coal is everywhere covered by a hard blue whinstone, containing small nodules of lime spar. This whinstone is supposed by some to have a peculiar character, and is only met with in the vicinity of the coal, no rock of the same kind being found at a greater distance than a mile from the field. But in examining and comparing it with similar rocks, which are very abundant in that part of the country, it did not appear to me to exhibit much of that peculiarity of character now alluded to; or, indeed, to be at all different from much of the whinstone in the neighbourhood. It is of very variable thickness; but in some places not less than 100 feet. A stratum of sandstone and shale, or aluminous schistus in alternate layers, succeeds the whinstone, and is about 24 feet thick. The next stratum, going downwards, consists of two fathoms of soft till, or fire clay, intermixed with ironstone nodules. Next to this is the mass of coal, which in some places is from 50 to 60 feet thick. This immense body of coal is not, as has been represented in some vague descriptions, lying in a confused, irregular mass, but is composed of five distinct seams, which are separated from each other by a hard stone from 9 to 12 inches thick, or by ironstone bands. In the lowest seam there is a splent coal, the thickness of which is from 12 to 16 inches. The coal is again succeeded by whinstone; but this is said to be of a softer and brittler nature than that which covers the coal: and hence it appears that the coal and its accompanying strata in this field are included between two masses of whinstone.

The greatest thickness of the coal in this field is in that part of it where a double series of beds seems to overlap each other. This will be seen by consulting fig. 7, which exhibits a section of the strata. In another part of the same field two series of seams of coal also overlap one another; but are separated by a considerable thickness of sandstone. This distribution of the coal may be seen on the right hand of the section of the strata, given in fig. 7.

The regularity of the strata in this field is greatly interrupted by two slips or hitches, which produce a considerable dislocation of the strata, but without the intervention of a dyke or vertical stratum. In one of these hitches, which runs nearly in a north-north-west and south-east direction, the strata are thrown up on one side to the height of 50 feet; and in the other, in which the shift of the strata is about 30 feet, the course inclines rather more to the north. The effect of these dislocations in the strata may be seen at fig. 6 and 7.

The general distribution of the coal in this field may be considered as in the form of a basin, but subject to considerable derangement within its limits; for in some places the inclination of the strata is very considerable, in others it is very small, and in some others the strata lie quite horizontal. To the north and west of this field coal is found under limestone and freestone; but the thickness and extent are not such as to defray the expense of working. On the east side of the field, there is a body of workable coal connected with strata similar to that of the Quarrelton coal, but on a smaller scale.

Riccarton coal.—This coal field, which lies south of the village of Riccarton, in Ayrshire, belongs to Mr Campbell of Treesbank, and is remarkable for containing an extensive bed of blind coal, the coal blende of the Germans. This coal has but a small proportion of bituminous matter in its composition, so that when it burns, it gives out no flame, and very little smoke. These qualities render it useful for many purposes, as in the drying of malt, where flame and smoke are inconvenient or injurious.

This coal field is bounded on the south and east by a great body of limestone, near which the coal, as is usually the case in such situations, is only in very thin seams. The following are the strata which are found in the coal field. The first is a bed of clay of about 7 fathoms in thickness; this is succeeded by a soft till of from 2½ to 3 feet thick, forming the roof of a bed of fire coal 3 feet thick. This coal is of the usual quality, burns with flame and smoke, and cakes somewhat like the Newcastle coal. Between this bed of coal and the next there are 13 fathoms of till or bituminous shale, and ironstone. Under this is the bed of blind coal, the thickness of which is 4 feet 4 inches, divided in the middle by a thin stratum of smooth bituminous shale, from 10 to 4 inches thick. The floor or pavement of the blind coal is a hard freestone. It ought also to be observed, that in the 13 fathoms between the two beds of coal, there are some thin strata of a shivery sandstone; but I could not learn that there is any considerable body of this rock in any part of the field.

The inclination of the strata in this field is a little to the west of south, and the dip is about 1 foot in 12; a slip or hitch, producing a dislocation of 20 feet, runs through the field from south-west to north-east. The coal is wrought at a moderate depth from the surface; the depth of the engine pit, by which the field is drained of water, does not exceed 21 fathoms.

It has been supposed by some theoretical writers on geology, that coal is deprived of its bitumen, and reduced to the state of blind coal, in consequence of having been in contact with whinstone in a state of fusion; but this opinion derives little support from the history of this coal field, as no whinstone is found in any part of it, either in the form of vertical or horizontal strata, and none of the rocks exhibit any indications of the action of fire.

Blind coal is not uncommon in different places of Scotland, although it is generally found in thin seams. It is met with near Cumnock, which is also in Ayrshire; in the parish of Shots, in Lanarkshire; in the parish of West-Calder, which has been already mentioned as the boundary of an extensive tract of coal, lying between Shots and Wilsontown; and in some other places.

Coal of Ireland.—I have heard it asserted by some persons, who, I fear, were more actuated by the warmth of patriotic zeal, than guided by sound knowledge, that Ireland possesses abundance of coal to be able to supply herself with that valuable fuel; but that numerous attempts in prosecuting its discovery, or in digging it out, have been discouraged and finally frustrated through the influence of the proprietors of coal in England and Scotland. Admitting the operation of such selfish conduct in English or Scotch miners, who are employed in searching for coal, it is difficult to conceive how it could extend to the skilful geologists and miners, who are natives of Ireland, resident in that country, and who, it cannot be doubted, are as strongly attached to her and to their own interests, as to those of the sister kingdoms. An assertion equally silly and groundless might have passed unnoticed, had it not been suggested by the consideration, that the cause of failure, in the discovery of coal in many parts of Ireland, must be sought for in the nature of the rocks, which are extremely unfavourable to the existence of coal, and over a great part of the kingdom are entirely destitute of that mineral.

The few and scanty notices which I have been able to collect of the history of the coal of Ireland, may be comprised in a few words. At Drumglass, in the northern part of the kingdom, Mr Whitehurst found the following strata accompanying coal, which, he observes, are perfectly analogous to the strata in the English coaleries.

	Feet.	Inches.
1. Clay and rublestone -	48	0
2. Soft argillaceous stone -	30	0
3. Bind, or indurated clay -	35	0
4. Shale - - -	15	0
5. Coal - - -	4	6
6. Argillaceous stone not cut through	0	0
	132	6

Mr Whitehurst adds, but on what grounds is not stated, that there is some probability of coal being found under the stratum No. 6 *.

At Ballycastle, where coal has been wrought for a long time, the strata have an inclination to the southward, and are remarkable for being covered by a thick bed of basalt or whinstone, which extends along the whole northern coast of Ireland. The following is an enumeration of the strata observed in the cliff facing the Atlantic Ocean, but without specifying the thickness.

1. Whinstone,
2. Firestone argillaceous,
3. Till, shale, or laminated clay,
4. Stone argillaceous,
5. Till or shale,
6. Freestone argillaceous,
7. Coal $4\frac{1}{2}$ feet thick,
8. Stone argillaceous,
9. Till or shale,
10. Brown limestone, containing no marine shells,
11. Bind, indurated clay,
12. Stone argillaceous,
13. Strata not ascertained, but of great thickness,
14. Millstone grit, containing quartz pebbles.

The last stratum enumerated is entirely covered by the sea at high water. The coal of this

* Inquiry into the original State of the Earth, p. 246.

place is wrought by means of a drift or road carried into the interior of the mountain; it commences in the stratum, No. 13, and is conducted through the strata intervening between that and the coal. By this road the coals are carried to the wharf to be shipped, and by the same passage, I suppose, the water is carried off from the mines *.

Strong indications of coal, it is said, have been observed in the counties of Down, Cavan, Monaghan, and Donegal. Some appearances also are met with on the western coasts. Bituminous schistus is seen along the maritime parts of the county of Clare; but here, it is remarked, that from the inclination of the strata, the coal veins seem to lie at a considerable depth, and the principal seam dips beneath the bed of the ocean. According to Mr Fraser, there are valuable mines of coal in the northern parts of the county of Cork; but the want of roads and canals has hitherto discouraged the extension of the operations, although it is said, that a canal might be carried from the works to the suburbs of the city of Cork, at so small an expense as L. 60,000, which would thus furnish the commodious means of access to a ready market. The counties of Kilkenny, and Queen's County abound with coal, which is chiefly situated in the mountains of Leitrim, where it is in

* Inquiry into the original State of the Earth, p. 259.

such abundance as to be sufficient to supply all the western districts of Ireland with fuel; and besides, for working the rich beds of iron ore, which are found in the vicinity of the coal mines *.

At Arigna, which is situated on a river of the same name, on the west side of Loch Alleyn, in the county of Roscommon, the beds of coal have been traced four square miles. In consequence of the abundance of coal and iron-stone, iron works, on an extensive scale, have been erected at this place, consisting of a blast furnace, a boring mill, a foundery, a forge, and slitting mill, either driven by water or a powerful steam engine. The thickest seam of coal which has yet been met with is on the Brahlieve mountain, where the works are situated; but on a neighbouring mountain, called Dobally, at the head of Loch Alleyn, a seam of 10 feet thick has been discovered. The latter coal, it is added, has been seen only at its outburst, where it is tender and culmy.

The coal at Brahlieve dips into the hill about 1 foot in 12; and at the distance of a mile on the other side of the mountain, where the coal is also wrought, the seam dips in a contrary direction, so that it lies in the form of a trough, or is what is called a *swilly* coal, in the middle of which it

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* Gleanings in Ireland by S. Fraer, Esq. 1802.

will be found flat; and, it is supposed, considerably thicker than it is elsewhere.

This coal, as well as the Kilkenny coal, is of the nature of blind coal; it burns with little flame and smoke to a white ash *.

A remark made by Mr Fraser, in the work already quoted †, must not pass unnoticed. He observes, that the coal brought by means of river and canal navigation, from the mines of Kilkenny and Queen's County, to the same market as that which is imported from Whitehaven or other parts of the English coast, is sold at double the price. Thus the Irish coal in the harbour of Waterford sells at 8 or 10s. while the Whitehaven coal is only 4s. per barrel of 4½ cwt. Now, unless the Irish coal be of a superior quality to that of Whitehaven (which I do not understand is supposed to be the case), it can only meet with a market when there is a deficiency of English coal; and it must follow besides, that the expense of working the Irish coal is, from peculiar circumtsances, much greater than that of England.

* Report by Mr Grieve, Civil Engineer, Edinburgh.

† Gleanings, p. 7.

SECT. III.

OF THE COAL OF FRANCE AND SOME OTHER COUNTRIES.

Before the revolutionary war of France, England enjoyed a very considerable trade in supplying the maritime parts of that country with coal. But being deprived of this supply during the interruption of free communication which war imposes between hostile countries, the rulers of France, whatever name they assumed, or whatever form of government they affected to maintain, seem to have been ever attentive to the improvement of her internal resources. Among other objects of research which promised to be useful to the state, the discovery of coal was too important to be neglected. It was accordingly eagerly attempted wherever any favourable indications offered; and appears in many cases to have been so successfully prosecuted, that France is supposed to have within her own territories not only an abundant supply of coal for domestic purposes, but also for the extraordinary consumption of numerous flourishing manufactories.

The inspection of a map * of France, in which the coal districts are delineated, would lead us to conclude, that more than one half of the kingdom contains mines of that valuable mineral; but when the accompanying descriptions are examined, the extent of country abounding in coal, or affording it in such plenty, and of such quality and thickness, as to allow the operations of digging and extracting it to be profitably conducted, must be greatly abridged; and it may be more than suspected, that speculations in the discovery of coal have been as much encouraged in France as in other countries, by those interested in so valuable an acquisition. It seems however not at all improbable, that the result of sober inquiry will bring the estimate of the extent of the coal districts of France, containing good workable coal, nearer to an equality with those of Britain than the flattering descriptions which have been given of the former would lead us at first sight to believe; and hence the general remark already made of the limited extent of coal strata, is still farther confirmed. But notwithstanding the abundance of coal in France, a curious fact has been noticed, and commented on in a report † addressed to the consular government, concerning

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* Jour. des Mines. vol. xii. No. 72.

† Ibid. vol. xi. p. 257.

the coal mines in the department of Jemmappes, which are held out as the richest and most valuable of any in the country, that the English coal carried by sea to the same market, Ostend for example, can be sold at a price nearly one third lower than the French coal. The reporter seems to be greatly at a loss to account for this remarkable difference, ascribing it sometimes to a prejudice, a well founded one I suspect, in favour of the English coal, and sometimes to the superior skill and more perfect machinery employed in conducting the operations in the English coaleries.

From a very elaborate report* drawn up by Lefebure, and containing a general view of the coal mines of France, it appears that coal is wrought in 47 departments of that kingdom, and that 16 others afford some indications of the same mineral. It seems to have been one object of the report, to ascertain the quantity of coals obtained from the different mining establishments throughout the kingdom. But of the 47 departments in which coal mines are wrought, the report of the product of 34 only has been obtained; and the estimated annual amount of the coal of these 34 departments is given at 388,095,000 myriagrammes, which is equal to about 3,880,000 tons; and making an allowance of one twentieth part of what is now

* Jour. de Mines, vol. xii. Nos. 71 and 72.

stated for the produce of coal in the 13 departments not included in the former account, 850,000 tons must be added, making the whole annual produce of the coal mines of France 4,730,000 tons. The above calculation, it is added, is rather under than above the truth.

The coal which has been found in some districts of the southern parts of France, as in the departments of the Lower Alps, the mouths of the Rhone and of Var, is accompanied with calcareous strata, and is of an inferior quality; but is at the same time a valuable acquisition in places where wood is scarce and various manufactures are established. The country in the vicinity of Alais, in the department of Gard, contains numerous and very rich beds of coal, some of which are of a good quality, and, with the advantage of water carriage, could be conveyed to the neighbouring districts, particularly towards the Rhone, and the large cities of Montpellier, Nismes, &c. at a moderate expense. Similar difficulties, in the want of navigable rivers and canals, are to be surmounted, before an abundant supply of coal can be obtained for other places in this part of the kingdom; as for Toulouse in the south, and Bourdeaux and Rochelle in the west, from the coaleries of Carmeaux in the department of Tarn, which affords a good coal. The richest mines of coal in the south of France, are situated in the department of Aveyron, on the banks of the Lot and the Dordogne, at the upper part of its course. This part of the country is represented as containing immense masses of coal, which in many places appear very near the surface.

In the central parts of France great abundance of coal is met with; and particularly in some districts at no great distance from the banks of the river Allier, and that part of the country to the south of Lyons, included in the natural boundaries formed by the rivers Saone, Rhone, and Loire. Mines of coal have been also discovered in the departments of Creuse and Allier, and particularly in the neighbourhood of Commentry, in the latter department. Towards the north-east in this part of the kingdom, and in the department of Lanievre, coaleries have been established, from which Orleans and Paris, and other towns in the interior of France, are supplied with fuel. This coal is said to be of an inferior quality, but is found to answer the operations of the forge, without being reduced to the state of coke. Farther to the east are situated the coaleries of Creusot, in the department of Saone and Loire; and not far distant there are some excellent beds of coal at Blanzy.

The coal in the eastern frontier of France, as in the department of Mont Blanc, seems, from the report, to be of no great importance. There is a thick bed of coal towards the source of the river Doubs, and on the boundaries of the department of the Upper Saone; and some coaleries have been established around the foot of the Vosges mountains, in the departments of the Upper and Lower Rhine; but the extent of their operations and produce appears to be extremely limited.

In the western parts of France, the mines of Montrelais have, for a long time, furnished a considerable supply of coal to that part of the country which is in the vicinity of the river Loire, and in the lower part of its course. The cities of Nantz, L'Orient, and Rochelle, as well as the maritime coasts of this part of France, are supplied with fuel from these mines. On the northern coast, in the neighbourhood of Bayeux and Caen, are situated the mines of Litry; and to the westward, that part of the country round Brest, Morlaix, and Quimper, is distinguished in the mineralogical map above alluded to as a coal district; but as it is passed over unnoticed in the report, only some trifling indications, I suppose, have been met with.

But that part of France which lies between Calais and the banks of the Rhine contains by far the richest coal mines in the kingdom; and indeed the produce of the mines in the northern districts amounts to three fourths of the whole produce estimated above. Some of the departments in the north-eastern parts of France are stated as possessing abundant mines of coal, particularly those of Mont Tonnerre, of the Rhine and Moselle, and of the Saarre.

I shall now finish the very general outline of the mines of France, given above, with a brief sketch of the history of three coal districts, some of which are distinguished by peculiarities unknown in this country.

Coal field in the district of Boulogne.—This district is described, according to a natural division, into the chalky and limestone territory; the former terminates in a ridge, which embraces the latter in the form of a semicircle, which extends to the sea-coast on the south, and to Cape Blancnez on the north, or that part of the French continent which is nearest to England. The coal mines, which have been wrought since the year 1692 are situated in the limestone territory. The limestone, some of which approaches to the nature of marble, and contains shells and other animal remains, covers the strata of aluminous schistus and sandstone which accompany the coal. The extent of the coal district is near 1000 fathoms from south to north, and about 600 from east to west; and in this space the dip or inclination of the beds of coal, and the accompanying strata, is in opposite directions. In the northern part of the district, the inclination is from south to north, but in the southern part it is from north to south. The principal operations have been carried on in the northern part of the district, where five beds of coal have been discovered. The termination of these five veins of coal is at the surface, and is regularly at the distance of from 25 to 30 fathoms from each other. The beds of coal, as they dip into the earth in the opposite direction, are interrupted by a dyke which runs in the form of a crescent from north to west. This dyke is composed of a variety of limestone, which is common in that part of the country; and although it has been penetrated near 200 feet, its thicknes is unknown. At the perpendicular depth of more than 600 feet, it presents the same appearances, after which it is succeeded by a schistose rock, which serves it for a base, and which also interrupts the coal and accompanying strata. The coal in the northern part of the district meets with similar interruptions, and appears to be cut off by the limestone. But according to the observations of other mineralogists, the dyke, or vertical stratum of limestone, is to be considered as a horizontal stratum brought nearly into a perpendicular position, rather than a vertical stratum or dyke. This is probably the fact, and it coincides with numerous other facts already noticed.

The northern part of this district, it has been stated, contains five veins or beds of coal. The first bed is covered with two feet of vegetable soil, mixed with flint, between three and four fathoms of clay, four fathoms of whitish marl, and eight fathoms of blue marl and aluminous schistus, the latter of which is the roof of the stratum of coal. This bed of coal is extremely variable and irregular in its thickness, running from a foot to a fathom.

The second bed is at the depth of not fewer than 68 fathoms from the surface; the thickness is much the same as the first. Between the first and second there are several small veins of coal, from six inches to a foot in thickness.

The third vein is 16 fathoms deeper than the second; and the intermediate space is composed of a very brittle schistus and sandstone. The thickness of this vein varies from 3 to 4 feet; but its thickness diminishes in its inclination, and also as it approaches the limestone, which cuts off the other veins.

Seventeen fathoms below the last vein is the fourth vein, which is about 3 feet 4 inches thick. The intermediate space consists also of sandstone and schistus. This vein has been traced to the limestone, by which it is cut off.

The fifth vein is at the depth of 14 fathoms below the fourth, through strata, which are also composed of schistus and sandstone. The thickness of this vein is 4 feet 4 inches; but it is divided by 16 inches of earthy matter, having one foot of coal above, and 2 feet under it. The operations in this vein have also been carried to the limestone. The whole depth from the surface is 115 fathoms.

The preceding sketch is of some importance to the practical miner, as it shows what has been oftener than once already noticed, that the coal strata in the immediate vicinity of limestone, or accompanied with strata of limestone rocks, rarely afford profitable mines of coal, or coal of a good quality, and fit for the ordinary purposes of fuel; and it may prove a useful lesson to those who are naturally disposed to indulge hopes of discovering valuable beds of coal in such circumstances, but whose sanguine expectations, after many serious and expensive operations, have been frustrated by disappointment. It is to be observed, too, that of the 5 veins of coal in the district alluded to, those at the greatest distance from the limestone, and particularly the fourth vein, which yields a good coal, are the most valuable, not only because they are less irregular, but also because the coal is of a better quality. The same observation applies to the veins of coal, as they approach the great mass of limestone by which they are entirely cut off. In the vicinity of that rock they become thinner, as well as more irregular, and it is very probable that the quality of the coal is greatly inferior.

Coal of Jemappe.—This department contains the richest mines of coal in France, and the most extensive operations are carried on for extracting it. A very large portion of this department is composed of coal strata, in which an immense mass of that mineral is deposited, and in many places it lies at no great distance from the surface.

Three different series, or depositions of coal, have been discovered in this department*; and each of the series is described as being more than three miles broad, of a very considerable length, and containing a great number of beds of coal, which are from $3\frac{1}{2}$ to $6\frac{1}{2}$ feet thick. The bearing of the strata of coal is from east to west, and the inclination is from north to south. The number of beds of coal varies in each series, and even in the same series, because some of them are not extended through its whole length.

Some notion may be formed of the extensive operations and produce of these mines, by considering the number of persons to which they give employment. It is said that no fewer than 25,000 persons are constantly occupied in the works below ground; and if the whole number engaged in the other departments of labour connected with the mines be estimated, it is supposed that they do not fall much short of 60,000; the number of pits or shafts now open is not less than 300.

Coal of Anzin.—This coal is situated in the department of the North. The working of the coal was begun near the commencement of the 18th

* Jour. des Mines. ii. p. 257.

century, and has been continued since, affording a very considerable produce of coal. The space occupied by the workings in this district is on the north-west of Valenciennes, immediately contiguous to the fortifications of that city, and it extends in length about 1½ mile, and in breadth about three quarters of a mile. The strata which accompany the coal are of the usual kinds, viz. sandstone and aluminous schistus, and the depth of the workings varies from 60 to 170 or 180 fathoms. The thickness of the beds of coal is not very considerable, varying from a foot to about 3½ feet; but in some sections of the strata, not fewer than 40 beds of coal of different degrees of thickness appear. But the most remarkable peculiarity of this coal is the manner in which it is distributed: Sometimes the strata or beds are nearly in a vertical position; sometimes they are considerably inclined, approaching nearly the horizontal position. But the most extraordinary circumstance in the history of the coal strata of this district is, that the same bed or vein of coal is met with at very different depths, in consequence of being folded back, as it were, either in an upward or downward direction; but this distribution of the coal strata will be best understood by examining Fig. 8. on Plate II.

COAL OF OTHER COUNTRIES.

No coal has yet been discovered in any part of Spain or Italy; and no indications of that valuable mineral, worthy of notice, have yet appeared in either of these countries. In other parts of the European continent, as in Silesia, Hessia, the Meissner, and Bohemia, there are valuable mines of coal, some of which yield it in considerable abundance. A mass of coal, somewhat resembling the Quarrelton coal described above, is met with at Meissen in Hessia. It is wrought by means of galleries, which are carried upwards into the side of the hill, and 900 feet under its summit, through sandstone, thin clay, and, lastly, a bed of coal from 6 to 90 feet thick, which latter is covered by a mass of whinstone 600 feet thick. The coal lies in a horizontal position *.

The greatest part of the northern countries of Europe, with the exception of a small quantity

* Miner's Jour. 1789, quoted by Kirwan, Geolog. Ess. p. 311.

found in the Russian territory, is entirely destitute of that combustible. In several places of the Russian empire, coal of an inferior quality is met with. Some appearances of that mineral were observed by Olivier on the shores of the Black Sea *; and Pallas says, that it is not uncommon to meet with pit coal in the vicinity of the Donetz, and towards the north of Taganrog, beyond the sources of the rivers which discharge their waters into that sea. At the distance of 150 versts from Taganrog, an immense bed of coal, no less than 24 feet thick, has been discovered; but it is mentioned that it is a slate coal of inferior quality †. The same author informs us, that the existence of coal in the neighbourhood of Moscow was first ascertained about the year 1763; but the quantity obtained is far from being sufficient for the supply of that immense city, or to render the importation of British coal unnecessary; and it appears from the short notice given of these mines, that no great advantage is obtained from them ‡.

The extensive countries included under Asia, China excepted, scarcely afford any indications of coal. On the Banks of the Pekiong, a river of

* Trav. vol. i. p. 141.
† Trav. vol. i. p. 502.
‡ Ibid. vol. i. p. 6.

China, which passes by Canton in its course towards the sea, coaleries were observed by some of the gentlemen in the train of Lord Macartney, during his embassy to that government. The coals are extracted by means of levels carried into the side of the hill, and are immediately put into vessels, to be conveyed to different parts of the empire. Several of these mines are said to be very extensive; but as the coal is described to be of a soft, shivery nature, it is probably of an inferior quality. Even the dust, or small of the coal, which is usually neglected in this country, is not lost by that industrious and economical people: It is mixed with soft earth, collected from the marshy grounds, reduced to the form of bricks, and being dried in the sun, is conveyed to those parts of the empire which are destitute of that necessary fuel *. The latter circumstance is a pretty obvious proof of the scarcity of coal, at least in that part of the country. It is said that coal is in general use in Pekin, which is supplied with abundance of that mineral from the mountains in the neighbourhood; but of the coal in the other parts of the Chinese empire, if any exist, no information has been obtained.

* Staunton's Embassy, vol. iii. p. 348. Barrow's Travels, p. 194.

No coal has yet been discovered in any part of the immense regions of Africa.

The extensive continent of South America, richly abounding in many precious minerals, seems to be entirely destitute of coal; but this valuable fuel is met with in different parts of North America. No coal, I believe, has ever been found in Canada; but in the island of Cape Breton, which has been already noticed by the author, there is a very extensive bed of that mineral. It is described as lying nearly in a horizontal position, and not more than 8 or 10 feet below the surface; but it seems to be so little valued in that country, that it is chiefly employed for the purposes of ballast; and one of the pits having accidentally taken fire, was allowed to burn, and not long since, it is said, remained unextinguished.

Coal is said to be abundant in various places of Virginia; and it has also been met with in some of the territories which border the Mississippi and Ohio. At Salisbury in Virginia, there is a bed of coal of the extraordinary thickness of 42 feet. This immense bed is so near the surface, that the earth which covers it is removed, and the coal is dug out like stones from an open quarry *.

Coal has been discovered in New Holland, on the banks of Hunter's River, now called Coal

* Phil. Mag. vol. xxv. p. 189.

River, from the abundance of that combustible found on its banks; a discovery which must prove of inestimable value to the infant colony of New South Wales. The mouth of the river where the coal is found is nearly in the latitude 33° South. No precise account is given of the natural history of the coal, or accompanying strata. It is only stated generally, that the strata of coal, which are of various qualities and degrees of thickness, run from one side to the other of the mountain in which they are distributed. But some notion may be formed of the abundance of this fuel, when we are informed that 40 tons were dug out and put on board a vessel in 11 days, one man only being employed in the mine. This circumstance shows that the bed of coal must be of considerable thickness, and that it lies near the surface. Similar strata of coal were observed in an island at the mouth of the river; but it is described as being of an inferior quality. Plenty of iron ore, it is said, and some indications of copper ore, were also found in the vicinity of the coal district *.

* Grant's Narrative of a Voyage of Discovery, p. 149.

SECT. IV.

OF SEARCHING FOR COAL.

The incalculable advantages to be derived from abundance of coal, not only for domestic purposes, but as the foundation of numerous important manufactories, have very naturally, at all times, excited a deep interest in mankind in the discovery and acquisition of that valuable mineral. With the obvious tendency to hope and believe what is wished and strongly desired to be true, it is little to be wondered at that men have been often deceived and disappointed, whether misled by the fanciful systems of the speculative, or imposed on by the specious arts of the practical discoverers of coal. Because one man possesses an excellent workable coal, his neighbour can see no reason why the contiguous territory should be destitute of the same mineral riches. Unacquainted, perhaps, with the narrow limits of coal districts in general, and overlooking the disturbances and dislocations that may have taken place in the strata, or not adverting to the commencement of a new series of rocks, he is encouraged to prosecute expensive and fruitless researches; the result of which, from an accurate knowledge of the natural history of coal, might have been certainly predicted to be loss, vexation, and disappointment.

It is not my intention at present to enter into a detailed account of the methods of searching for coal; and indeed the minute directions on the subject already given by the Author * render this unnecessary. I shall therefore only throw out some general cautions, the observance of which may be useful in the proceedings to be adopted in researches of this kind; and these cautions, it ought to be noticed, although in some cases they may admit of a more extensive application, refer chiefly to Scotland.

In the first place, when hopes of finding coal, in places without the boundary of the general coal district of Scotland, are encouraged even by what may be considered as favourable appearances, the proprietor or adventurer in the speculation on whom the expense of the research falls, ought to proceed with the utmost diffidence in so doubtful an investigation, where so many chances of a successful discovery are against him: For he may be assured, that the nature of the rocks, almost in all

* Chap. x. vol. i.

places of Scotland beyond the limits already described, absolutely precludes the hope of discovering coal in such situations. Slight indications of that combustible may sometimes occur; strata of sandstone, not very unlike the sandstone which accompanies coal, with beds of ironstone and bituminous shale, may present themselves, and even a thin stratum of coal itself may occasionally appear; but a workable seam of good coal is scarcely at all to be expected. Of this kind were the researches for coal in Sutherland and Caithness, which were carried on a few years ago at an expense to government of more than L. 1000; every penny of which might have been saved, had sufficient attention been paid to the natural history of coal and its accompanying strata. Not many years before, a similar expense of at least half the amount, which was defrayed by the subscriptions of private individuals, was incurred in the same fruitless attempt.

Great encouragement has been held out to the proprietors of Dumfries-shire, to indulge the hope of discovering coal in different places of that county; and in that hope, no trouble or expense has been spared in prosecuting the discovery: But from the nature of the rocks, so far as I have had an opportunity of examining them, from the report of surveys * made on purpose, and,

* Jameson's Mineralog. Survey.

above all, from the actual examination of the strata by boring, I think it may be safely asserted, that there is not one favourable indication of coal in any part of that county, excepting the small patches at Cannoby and Sanquhar, where it is already wrought. The nature of the rocks is exceedingly unfavourable to the existence of that combustible; and perhaps a more rigid comparison of the strata with those of coal countries, might have precluded farther research, at least with any hope of success, and thus prevented the very considerable expenditure required for carrying it on. But it appears to me that this matter is put beyond dispute, and, unfortunately at the same time for the inhabitants of the county, even the expectation of making new discoveries of coal in Dumfries-shire, must be abandoned in consequence of the borings above alluded to. It is to be presumed that these borings were made in places where the indications of coal were somewhat favourable; and this being the case, they afford little ground to hope for the existence of that mineral in other places, where the appearances are uncertain and doubtful. In one place, at Repentance Tower, near Hoddam Castle, a shaft was sunk to the depth of 86 feet; but the result of this trial was not more fortunate *.

* See the Sketch of the Mineralogy of Dumfries-shire, by General Dirom, on the County Map.

It has been said that part of Dumfries-shire forms one side of the great bason which contains the Cumberland coal; and according to this opinion, there is a strong probability of finding coal in the former county. It is true that coal strata are often disposed in the form of a basin: but this does not hold universally; for there are numerous instances where the inclination of the strata of a coal district continues the same through its whole extent. It has been said also, that the red sandstone of Dumfries-shire is of the same nature with that of Cumberland, which accompanies the coal. Having had no opportunity of examining the red sandstone of Cumberland, I cannot decide on this comparison, which I suspect has not been accurately made. But I have no hesitation in asserting, that no workable coal will be found in the vicinity of any of the red sandstone of Scotland.

But it is not only necessary to be cautious in indulging the hope of discovering coal in places beyond the general range of the coal districts of this country, a similar caution is not less requisite in searching for it in places in the immediate vicinity of a workable seam of coal, where a change is observed in the distribution of the strata, or where a new series of rocks has commenced. In the first case, where the position of the strata is changed, the nature and extent of the derangement, or dislocation of the strata to which the change seems to be owing, ought to be correctly ascertained; because the seam of coal which in one field lies near the surface, and is wrought with profit, may, in consequence of the dislocation of the strata, be thrown down to such a depth in the adjoining field, that it becomes quite inaccessible.

There is still less hope of finding coal in places where a change in the nature of the strata has taken place, or a new series of rocks has commenced. The strata on the banks of the water of Leith near Slateford, and on the estate of Craig-lockhart in the vicinity of Edinburgh, on which some expensive trials for coal were made two years ago, afford an illustration of this point; for the position of the strata, and also the nature of the rocks, are different from what they are in the coal district, to which they may be considered as almost immediately contiguous. A thin seam of coal was discovered in a quarry, on the north side of the road from Edinburgh to Collington; and in the expectation that it would improve in thickness to the dip, shafts were sunk in several places; but the result of all these trials proved unsuccessful. The Author of the preceding work has asserted from extensive experience, that a regular bed of coal, after it has been fully traced between the roof and pavement, is never found to increase in thickness. Proceeding on the same opinion, which perfectly coincides with my own observations, I ventured to predict, with some degree of confidence, that the termination of the last trial which was made would not be more successful than the preceding. Unfortunately for that part of the country in general, and for the proprietor in particular, at whose expense the researches were conducted, that prediction was fully verified; for when the shaft was sunk to the coal, it appeared no thicker than it is found in the quarry where it was first discovered.

As coal strata are usually disposed in flat countries, an ocular examination becomes in these circumstances impossible. But as it is of great importance to acquire an accurate knowledge of their nature and thickness, and particularly of the nature and thickness of the beds of coal which are expected in the field before the expensive operations of sinking shafts are undertaken, information of this kind is obtained by boring. The apparatus in common use for this purpose, which is well known to miners, is not always to be depended on for the accuracy of the results which it affords. This uncertainty arises sometimes from the unskilfulness or fraud of those employed in the operation, and sometimes, perhaps, it is entirely owing to unintentional error. About twenty years ago, a bore hole was put down in a coal field in Mid Lothian. The operation was conducted by experienced workmen, and the report announced, that a bed of coal of only a few inches thick was penetrated, where one of considerable thickness was expected, and where an excellent seam of six feet thick was afterwards discovered, and has continued for some years to afford an abundant produce.

Not long since, a professed discoverer of coal undertook to search for that combustible, by boring in a district of Ayr-shire, where it would have been an invaluable acquisition. In the progress of his labour, the inhabitants were flattered with the most certain hopes of success; and at last, to their great joy, they were informed of the welcome discovery of the object of research. Contributions to defray the expense, and to reward the discoverer, which were formerly granted with a sparing hand, were now liberally made; and specimens of the coal, in the form of powder, in which state it can only be obtained from the nature of the operation, were exhibited. But as the fraudulent are not always consistent, some deviations in the narrative of his proceedings excited suspicion, and led to an investigation; in the course of which it appeared, that the coal produced in the day was secretly conveyed into the bore hole during the night. It must be noticed, that the rocks selected for the scene of the above operations are red sandstone, in which coal can never be expected.

An apparatus for boring has been proposed by Mr James Ryan of Queen's County in Ireland; the judicious application of which may certainly correct the errors, and prevent the frauds now alluded to. This instrument, for the use of which Mr Ryan has secured the exclusive privilege by patent, is an auger with teeth, something in the form of the trepanning instrument of surgeons. Its superiority over the boring instrument in common use consists in this, that a solid cylinder or core of the rocks through which the instrument passes, can be obtained; and in this way their nature and thickness can be more precisely ascertained, than when they are reduced to the state of powder by means of the chisel of the old instrument. Cores or cylinders from 2 inches to 2 feet in diameter, and from 6 inches to 5 feet in length, according to the dimensions of the borer employed, can be formed, and they are extracted from time to time by means of a pair of self-closing tongs. But this is not the only advantage of Mr Ryan's apparatus. If the cylinders produced be not of too small diameter, not under 6 or 8 inches, by placing them, after they are brought up, in their relative position with respect to the points of the compass, an accurate knowledge of the inclination of the strata may be acquired. After the core is formed by the auger, and the borer is drawn up, another instrument is introduced for the purpose of marking the top of the core with two lines at right angles to each other. One of the lines may be thicker than the other, or be otherwise distinguished to denote north and south; and the impression being made to correspond with the cardinal points, shows exactly what was the natural position of the cylinder, and consequently of the whole stratum. This is a most important piece of information in directing the future operations of a coal field which has been hitherto unexplored.

Mr Ryan's boring machine has been much approved of by the Dublin Society, the Board of Agriculture of London, Mr Dickinson of the Seaton Iron Works near Workington, and Mr Curwen of the same place, who have either seen the machine actually at work, or the cylinders produced by it. The following is the account of its operation by Mr R. L. Edgeworth, in an experiment made in presence of that gentleman: "Two men," he says, "relieved from time to time, cut a truly circular hole 5¼ inches in diameter, through a block of hard limestone, leaving a *core* a little taper of 4½ inches diameter, and 6¾ in length, which core is now in my possession. It is as true and as smooth as if turned and polished in a lathe, and the under surface shows exactly the fracture by which it was detached from the block at bottom.

"By this contrivance mines may be ventilated at small expense; the specimens of strata that are bored through may be brought up whole and unmixed, no deception can take place; and not only the dip, but the fracture, lap, and accidents to which each stratum is liable, may be determined at any depth. True vertical and horizontal sections may be previously obtained of any spot where it is proposed to sink shafts; and the subterraneous topography of a whole district may be laid down upon a map with great confidence, before any great expense is hazarded on mere speculation *."

But in justice to a very ingenious man, Mr Scott of Ormiston in East Lothian, it must be observed, that an instrument exactly of the same nature has been long employed by him for the purpose of extracting a core or cylinder of the coal, and thus ascertaining its thickness. About a year ago I had an opportunity of seeing the individual instrument used by Mr Scott. I do not know, however, that it was ever applied to rocks in general, or in any other way but to determine the thickness of the coal when it is discovered by the common apparatus. In this general method of using the new apparatus, therefore, Mr Ryan's exclusive privilege may perhaps be considered as perfectly entire.

CHAP. IV.

OF THE NATURAL HISTORY OF METALLIC ORES.

METALLIC substances, as they exist in the ores from which they are extracted, are found, either in the state of native metal, and in this state they

* Nich. Jour. vol. xv. p. 83.

are usually alloyed with some other metal, as gold, with silver or copper; or in the state of sulphuret, when they are combined or mineralized with sulphur; or in the state of oxide, when they are combined with oxygen; or in that of salt, as they are united with acids. Some metals, as gold and platina, have never been found but in the metallic state; because they are with difficulty acted on by chemical agents, while other metals are never met with in the metallic state, in consequence of the strong affinity between them and the substances with which they are usually combined; but there are others still which exist in all the different states above enumerated. Silver is an example of this, as it is found native, in the state of sulphuret, in that of oxide, and also in the state of salt.

Some metallic ores exist in great abundance in nature, while others are very sparingly distributed. Gold is met with in almost every country of the world, but in most places in small quantity. Iron is abundantly and universally diffused. The repository of some metallic ores is sometimes limited to a very few spots on the surface of the earth. Thus platina has only been found in two or three places in South America; a very slight trace of it only has been met with in any other country. Mines of tin are only known in a very few countries. Some metallic ores, again, are disposed in very considerable masses, as galena or the sulphuret of lead; others are met with in smaller quantity, and usually accompany other ores, as the ores of zinc, which are generally found in lead and copper mines; and the ores of bismuth, cobalt, and nickel, which are usually also met with in mines of copper and lead.

SECTION I.

ORES OF PLATINA.

This metal always exists in the metallic state, and it is usually found in the form of small, flat, or rounded grains. The colour is light steel gray, or silver white; it is ductile, and in thin plates flexible. Specific gravity 15·6 to 17·7; but when purified and hammered 23. Platina is infusible without addition, or in the focus of a burning-glass, or exposed to the action of oxygen gas. It is only soluble in nitro-muriatic acid, and does not amalgamate with mercury.

Platina was first known in Europe about the year 1748, and till lately, that Vauquelin detected about one tenth of this metal in a gray silver ore from the mine of Guadalcanal in Spain, it was only found in South America, and in alluvial soil which is covered with rounded masses of basalt; so that its native repository is unknown. The platina is accompanied with particles of gold and iron, and with another ore, which contains two of the new metals, osmium and iridium: this ore is not malleable. Rhodium and palladium, two other new metals, are alloyed with platina.

SECTION II.

ORES OF GOLD.

Gold, although one of the scarcest metals, is universally distributed. It is most frequently found disseminated, or in detached grains, or in a reticulated or dendritical form, and sometimes crystallized. The specific gravity of pure gold is 19·64. The colour of the ores of gold varies according to the nature and proportion of its alloy. This alloy is usually silver or copper, and sometimes iron, or, it is supposed, a small portion of platina.

Repositories of Gold.—Gold is frequently found in primitive mountains, where it is usually distributed in veins, and sometimes disseminated in the rock itself. The gangue or the matrix of gold, or the substances which accompany it, are quartz, feldtspar, limestone, pyrites, some of the ores of silver and galena. It is also met with in combination with manganese, cobalt, and nickel. Gold has also been found, it is said, in fossil substances, as in petrified wood penetrated with siliceous earth, a mass of which was dug out at the depth of 50 fathoms in an argillaceous breccia, or, as is supposed by some, a porphyry having an argillaceous basis, in Transylvania. This fact is assumed as a proof of the more recent formation of gold; and this opinion is farther confirmed by the discovery of Patrin, who found native gold surrounded by muriate of silver in the mine of Zmeof in Siberia; and muriate of silver is considered as comparatively a late production.

But gold is also common to alluvial soil, where it is disseminated in grains, along with siliceous, argillaceous, and ferruginous sand, which are the principal component parts of certain soils. It is also met with in the sand of many rivers. It has been observed that the gold is most abundant in the sand of rivers, when the waters are at the lowest, and particularly soon after floods; from which it is inferred, that the gold is carried down along with the earthy matters which are swept off by the violence of the current. It has been supposed too, that the gold found in the bed of rivers has been detached, with the force of the waters from the veins of the primitive rocks, which are traversed by these currents; and, according to this opinion, attempts have been made to trace the source of these auriferous sands, in the hope of discovering the native repository of that precious metal: but these attempts have usually failed; for it appears that the gold is peculiar to the alluvial soil through which the stream is carried, and is limited to the very spot where the gold is collected. This point seems to be fully established by the observations of naturalists. 1. The soil of certain plains through which rivers flow, frequently contains, to a certain depth, and in particular places, particles of gold. 2. The bed of the auriferous rivers yields a greater proportion of gold, after the plains which are traversed by these rivers have been flooded. 3. It has been very generally observed, that gold is found in the sand of rivers in a very limited space. When the sand of these rivers is examined higher up, and nearer to their source, no gold is found; so that if this metal were derived from the rocks which are abraded by the currents, the quantity would be greatest nearest to their sources; but observation has proved the contrary. Thus the river Orco contains no gold but in that part of its course between Pont and the place where it joins the Po. The river Tesin affords no gold till it has traversed lake Major, where its course must have been retarded, and where all the heavy particles of matter which it carried along with it from the primitive mountains must have been deposited. The quantity of gold collected on the Rhine near Strasburgh is greater than what is found near Basle, which is more in the vicinity of the mountains. No gold has been discovered in the sands of the Danube during the first part of its course; it is only in the plains below Efferding, which are traversed by that river, that the sands become auriferous. A similar remark is applicable to the river Ems: the sands of the upper part of that river, as it traverses the mountains of Styria, contain no gold; but from the place where it enters the plain at Steyer, till it join the Danube, the sands are auriferous, and sufficiently rich to be washed with advantage.

As a farther illustration of the natural repositories of gold being limited to particular spots, other facts may be noticed. The river Nera in the Bannat of Temeswar, in Upper Hungary, has been long known to yield gold dust. The strata on the banks of this river are, 1. about a foot of vegetable mould; 2. two feet of loam; 3. pebbles and calcareous earth, 1½ feet; 4. pebbles, pieces of other rocks, mica, garnets, and iron sand, 3 feet. This last is the stratum which affords the gold dust. In examining the extent of the gold-impregnated stratum, a shaft was sunk to the depth of 1½ fathom; 30 loads of the sand were dug out from this pit, and being washed, yielded 2 grains of gold. Another shaft was sunk 28 fathoms nearer to the foot of the mountains, and the same quantity of sand being dug out and washed, produced only half a grain of gold. At the distance of 22 fathoms to the south, another shaft was sunk, but the strata through which it was carried were entirely different. This gold-impregnated stratum not only becomes poorer as it approaches the mountains, but it has been also observed to become richer in proportion to its depth under ground. The iron with which the gold is accompanied in this stratum is in the form of black shining particles, which are attracted by the magnet.

In the history of the gold-impregnated stratum now described, it is stated that it rests on a bed of coal; and this fact leads to an opinion that coals are to be found in every gold-washing ground. In support of this opinion, it is mentioned, that coal beds appear every where on the banks of the Danube and the Ems, where gold is found, and particularly on the banks of the Danube from Vienna to Passau*. But it is remarked, that the gold-impregnated stratum on the banks of the Nera does not correspond in its position to the inclination of the strata of coal and marl which it immediately covers; it is constantly found parallel to the turf and vegetable mould†.

Most of the auriferous sands in all parts of the world are of a black or reddish colour, and are con-

* This fact does not hold universally; for there is not the slightest indication of coal at Leadhills, where gold is found.

† Born's Travels, p. 76—91.

sequently ferruginous. This circumstance, connected with the gold of alluvial sand, has led naturalists to suppose that it is owing to the decomposition of auriferous pyrites. It was observed by Reaumur, that the sand which accompanies the gold of most rivers, and especially that of the Rhone and the Rhine, resembles the gold sand of Ceylon. It is composed of particles of iron, and small grains of rubies, corundum, and hyacinth. Titanium has also been detected in the same sand. The gold obtained from alluvial soil is supposed to be purer than that which is immediately obtained from solid rocks; and from this it is supposed that its origin has been different.

It seems to be doubtful whether gold is to be considered as a volcanic production, or whether it has been met with in any volcanic territory.

Such are some of the general facts relative to the repositories of gold. It remains now that I notice the more remarkable places where gold has been found and collected; and I shall begin with those of Europe.

Scotland.—It would appear that gold was collected at a very early period in Scotland, and particularly in the mining field of Leadhills. The most extensive operations for that purpose were carried on by Bulmer, an Englishman, in the time of Queen Elizabeth. The trenches, heaps of soil that were turned up, and other marks of these operations, are yet visible near the road between

Leadhills and Elvanfoot, and still retain the name of Bulmer's Workings; and the place where the gold was washed is still called the Gold Scour. At that time, it is said 300 men were employed in searching for gold; and in the course of a few summers a quantity was collected equal in value to L. 100,000 Sterling. Not many years ago, similar operations were resumed by the advice of a German. Gold was still found; but I do not understand that the quantity collected was equal to the expense. During the last attempt, the operations were carried on under the superintendence of the late Mr John Taylor, manager of the lead mines at Wanlockhead. The gold was found immediately under the vegetable soil; and the method of conducting the operation, was to direct a small stream of water, so as to carry this soil along with it to basins or hollow places, where the water might deposit the matters carried down by the force of its current. The matter thus deposited was repeatedly washed till the whole of the earthy substances were carried off. The gold being heaviest, sunk to the bottom, and remained behind. Mr Taylor informed me of a curious fact, which he observed during the progress of these operations. He found that the gold was always most abundant near the top of the lead veins, that is, near the place where the veins come to the surface, as they traverse that country. He was so satisfied of this circumstance, that he could tell, merely by the quantity of gold increasing or diminishing, when they approached to a vein, or receded from it. Does this fact show any connexion between metallic veins and the formation or deposition of gold?

The soil of that country still furnishes gold; but whether the quantity be less than formerly, or the expense of collecting it, in consequence of the difference in the price of labour, be greater, the produce is by no means equal to the expenses. Searching for gold, therefore, is now regarded only as an amusement, and occasionly occupies the leisure hours of some of the miners.

Ireland.—The alluvial soil in other places of the British empire also furnishes gold. In the year 1796, a piece of gold, about half an ounce weight, was found by a man in the stream of a small river on the mountains of Wicklow in Ireland. This excited the attention of the country people, who began to search for gold, and continued their operations for nearly two months, when they were interrupted by an order from government. It is said that the sum of L. 10,000 Irish was paid for the gold found, and sold on the spot; the average price at which it was sold was L. 3. 15s. per ounce, making the total amount of the gold collected at that time equal to 2666 ounces. The ore was so pure that its specific gravity was 19, and 24 grains yielded, when assayed, above 22½ grains of gold. The greater part of it was entirely free from stony matter; but some of it was attached to quartz, or a fine grained ironstone, and sometimes disseminated in those minerals. In the course of the operations, several masses of native gold, exceeding an ounce in weight, were found in the soil. One mass was discovered which weighed 5 ounces, and another, amounting to no less than 22 ounces; which latter is said to be the largest specimen of native gold ever discovered in Europe.

The space where the gold was collected is of very limited extent, not exceeding 350 yards along the banks of the brook mentioned above in which the first piece of gold was found. The brook is only about six or seven feet wide; and before the operations commenced, had formed its channel down to the surface of the rock. The banks of this small stream in the above limited space are composed of a stratum of sand and gravel about five feet thick, which reposes immediately on a rock of argillaceous schistus, which latter is intersected by veins of quartz. It is from this sandy stratum that the particles of gold were extracted by washing in the manner already described *.

France.—A mine of gold was discovered in 1781 at Gardette, in the valley of Oysans, and in the department of Isere in France. This was a regu-

* Fraser's Wicklow, p. 19.

lar vein of quartz, traversing a gneiss mountain and containing auriferous sulphuret of iron, besides some fine specimens of native gold; but the quantity obtained was found unequal to the expense of the operations. Many of the rivers of that country, such as the Rhone, the Rhine, the Garonne, as well as others of smaller note, furnish auriferous sand; and gold, it is said, is found among the black sand and particles of morassy iron ore in the vicinity of Paris.

At the foot of mount Rosa in Piedmont, veins of auriferous sulphuret of iron traversing gneiss rocks have been discovered; and although the pyrites do not yield more than 10 or 11 grains of gold from the quintal, it has been found worth while to continue the operations. Some of the rivers, and various parts of the soil on the south side of the Appenine mountains, are also auriferous.

Spain and *Portugal*—have been famous from the earliest times as repositories of gold, not only in alluvial soil, and the beds of rivers, but also in regular veins; and it is supposed would still be the richest country in Europe for that precious metal, were it not that the colonial territories of those countries afford it in greater abundance. Gold was collected in the peninsula by the Phœnicians, and afterwards by the Romans. The latter people obtained annually 30,000 marks, or 240,000 ounces of gold from that country, and chiefly from Portugal, Gallicia, and the Asturias.

Schemnitz and Cremnitz are the most remarkable places in Europe, not only for mines of gold, but also for auriferous sands. The gold of Schemnitz is accompanied by silver, lead, and iron pyrites, and the matrix is quartz. The celebrated gold mine of Nagyag furnishes gold in combination with native tellurium; and in the mine of Edelfors in Sweden, native gold and auriferous iron pyrites are deposited in a vein of brown quartz, which traverses a mountain of schistose hornstone. The gold is also met with disseminated in the rock itself.

Asia.—The whole extent of the immense continent of Asia furnishes gold in greater or smaller proportion. The Siberian mines, and particularly that of Beresof, yield auriferous pyrites in a state of partial decomposition, and disseminated in a vein of quartz. In the southern parts of Asia, the sands of many of the rivers contain gold. The Pactolus, a small river of Lydia, is celebrated in antiquity for the great quantity of gold which it afforded, and is supposed to have been one of the chief sources of the extraordinary riches of Croesus. The numerous islands of the Indian Archipelago, as Java, Japan, Formosa, Ceylon, Sumatra, Borneo, and the Philippines, have been long celebrated for the quantity of gold which they afford, and are supposed to be rich in that precious metal at this day. In the extensive continent of India, gold seems to be most common in the kingdom of Siam.

Africa.—Beside what was brought from Spain, the greatest quantity of gold which the ancients possessed was obtained from Africa. The gold of Africa still forms an important article of commerce. It is always in the state of dust, which is considered as a proof that it is chiefly extracted from alluvial soil. The northern parts of Africa yield but little gold; but in the middle and southern regions, there are three or four places remarkable for the quantity of gold which they afford. The first is that part of the country which lies between Darfur and Abyssinia. The gold collected there is brought to market by the negroes in quills of the ostrich and vulture. This territory, it would appear, was known to the ancients, who regarded Ethiopia as a country rich in gold.

The second principal source of gold dust in Africa lies to the south of the great desert Zara, and in the western part of that continent. The gold is collected in that extensive flat which is bounded by the lofty chain of mountains, among which the rivers Senegal, Gambia, and Niger, have their origin. Gold is also found in the sands of all these rivers. Bambouck, which is situated to the north-west of these mountains, furnishes the greatest part of the gold which is sold on the western coast of Africa, as well as that which is brought to Morocco, Fez, and Algiers, and to Cairo and Alexandria in Egypt. It has been remarked by those who collect gold in that territory, that it is most abundant in an arid barren soil.

A third region of Africa where gold is abundant, lies on the south-east coast, between 15° and 22° of south latitude, and nearly opposite to Madagascar. The gold of that country, it is said, is found not only in the state of dust, but also in veins; and it is supposed that Ophir, from which Solomon obtained gold, was a country on the same coast.

Nearer to the equator, the gold coast supplied the Portuguese, and afterwards the Dutch, with immense treasures in gold dust.

America.—In modern times, America is the richest country of the world in this precious metal. In that country the gold is chiefly collected in the alluvial soil, and in the beds of rivers; and sometimes, but more rarely, it is obtained from veins. In Mexico, the gold is chiefly found in the silver veins, which are numerous in that country. All the rivers in the province of the Caraccas, about 10° north of the equator, furnish gold. In the Spanish part of America, gold is obtained from the alluvial soil in Chili, and also in the province of Choco, where it is more abundant; but in Peru it is extracted from veins of greasy quartz, marked with ferruginous spots. Helms has enumerated 30 mines or pits, from which gold is obtained in the viceroyalty of La Plata, or Buenos

Ayres. This enumeration includes not only gold veins, but also the places in the alluvial soil, or the beds of rivers, from which it is obtained by washing. In the argillaceous slaty mountains around Mojos, a town in the same kingdom, he observed many veins of quartz containing gold, with copper ore, lead ore, and iron spar; and from the alluvial soil near the same place, gold is extracted along with magnetical iron sand. The whole ridge of the Cordilleras, from the town of La Paz to Sicasica, abounds in rich gold ore. About 80 years ago, a projecting part of the rock, which is argillaceous schistus, fell down, and from this stone masses of pure gold, weighing from 2 to 50 lbs. were detached.

The following is the quantity of gold obtained from the Spanish possessions in South America in the year 1790, reduced to Sterling money.

Mexico	-	L. 112,525
Lima	-	147,126
Potosi	-	53,722
St Jago	-	129,314
		L. 442,687 *.

The above is the amount of the gold coined in the royal mints in the course of one year; but to

* Helm's Travels, p. 141.

this must be added a considerable proportion of the same metal fabricated into various utensils for churches, convents, and private individuals, beside the sums which are clandestinely exported by merchants, without being coined, which is supposed to be equal to one third, or even to one half of the whole amount.

A very great proportion of the gold of commerce comes from the Portuguese possessions in the Brazils. In that country it is collected in the alluvial soil, and in the sand of rivers, and extracted by washing. Gold is found almost every where throughout that wide territory, along the foot of the immense chain of mountains which lies nearly parallel with the coast, and extends from 5° to 30° of south latitude.

A considerable quantity of gold has been of late years collected in North Carolina. It is there found in alluvial soil, or in the beds of rivers; and it would appear from the chalybeate springs which have been discovered in the territory which affords the gold, that the soil is ferruginous. Such is the abundance of gold found in that soil, that a quantity of sand and gravel taken from a small spring, and which could be carried between the hands, afforded, on washing, a piece equal to a dollar, and two pieces equal to half a dollar in value, besides some smaller particles. And indeed so favourable are the indications of finding gold, that a company has been established, which has purchased 35,000 acres of land, for the purpose of searching for gold. In a very short time 40,000 dollars worth of gold was got from a surface of 400 acres; and the appearances were so favourable, that 100,000 dollars worth was still expected. The gold, it is said, is perfectly pure, and requires no refining *.

I shall now conclude the sketch which has been given of the natural history of gold, with a view of the quantity of that precious metal which is annually obtained from the different countries of the Old and New World, taken on an average between the years 1790 and 1802 †.

Old Continent.	*Kilogrammes.*	
Siberia - -	1700	
Africa - -	1500	
Hungary - -	650	
Saltzburg - -	75	
Norway - -	75	
Total of the Old Continent	———	4000
New Continent.		
North America -	1300	
South America -		
Spanish Possessions -	5000	
Carry forward,	6300	

* Thornton's Letter, Phil. Mag. vol. xxvii. p. 261.

† Brongniart, vol. ii. p. 351.

Brought forward,	6300	
Portuguese Possessions	7500	
Total of the New Continent		13,800
		17,800

The kilogramme being estimated at 2 lbs. 3 oz. 5 drs. Avoirdupois, the whole amount is equal to about 39,285 lbs. Avoirdupois.

SECT. III.

ORES OF MERCURY.

MERCURY remains in the liquid form in the ordinary temperature of the atmosphere; but when the temperature is reduced to 40° below 0 of Fahrenheit, it becomes solid and malleable. When solid, the sp. gr. is about 15·61.

Ores of Mercury.—The ores of mercury exist, either in the state of native mercury, or in that of alloy or native amalgam; in that of sulphuret, or cinnabar, which latter is sometimes impregnated with a bituminous clay; or in that of salt, or muriate of mercury.

Native mercury is of a tin white colour, and the specific gravity is from 13·56 to 13·58.

Native amalgam, which is an alloy of from 64 to 75 of mercury with 25 or 36 of silver, communicates to copper, by friction, a silvery colour. It is usually in the form of thin plates or leaves, but is sometimes crystallized in octahedrons. The colour is also tin white, and the lustre shining.

Sulphuret of mercury, or cinnabar, is distinguished by its fine colour, which is cochineal or carmine red, and its shining scarlet red streak. The spec. grav. is 6·90 to 7·86. It is usually crystallized, and the crystals are confusedly grouped together. It is entirely volatilized before the blowpipe, giving out a blue flame, and a sulphureous odour. The constituent parts of this ore are, mercury 81, sulphur 15, with a small proportion of iron.

A variety of cinnabar, of a brighter red colour, and of a fibrous texture, which is supposed to be owing to an admixture of radiated sulphuret of iron, is sometimes, but rarely, met with; and another variety, denominated alkaline cinnabar, is supposed to be common cinnabar impregnated with an alkaline sulphuret. A variety of cinnabar is known sometimes to exist in the state of powder, when it is denominated *flowers of cinnabar*, or native vermilion.

Liver, or hepatic ore of mercury, which is either in a compact or slaty form, is of a lead gray or cochineal red colour, with a deep cochineal red and shining streak; spec. grav. 7·18 to 7·93. This ore is composed of cinnabar, with a portion of indurated bituminous clay.

Corneous ore of mercury, or muriate of mercury, is a late discovery, and it is yet of rare occurrence. This ore is of a pearl gray colour, and is entirely volatilized before the blow-pipe, and without decomposition. The constituent parts are about 70 of mercury and 29 of muriatic acid, with a small portion of sulphuric acid.

Repositories of the Ores of Mercury.—Mercury is not one of those metals which is very universally diffused; and although it is accumulated in considerable quantity in the places where it exists, the repositories of this metal, so far as they have been yet discovered, are limited to a few spots on the globe.

The ores of mercury are but rarely met with in primitive mountains. According to Spallanzani, a sulphuret of mercury has been met with, disseminated in granite, in the Venetian territory; but by far the greatest proportion of the ores of that metal are found in secondary rocks, as in bituminous schistus, in compact limestone containing shells, in ferruginous sandstone, and even in ferruginous clay; and the ores are more usually distributed in large confused masses than in regular veins. Mercury, it is said, has been sometimes met with in volcanic territories. Dolomieu discovered mercury sublimed in an ancient volcano at Santo Fiora in Tuscany; but in investigating this fact, it would be necessary to ascertain, whether the ancient volcano here alluded to be not exactly of the same nature with the basaltic rocks of this country, which many of the French geologists ascribe to a volcanic origin.

The metallic ores which usually accompany the ores of mercury are, galena, or sulphuret of lead, sulphuret of zinc, hæmatites, iron pyrites, silver, and various ores of copper.

Mines of Mercury.—The principal mines of mercury are those of Deux-Ponts on the Rhine, of Almaden in Spain, of Idria in Carniola, and of Guanca Velica in Peru. This metal, indeed, has been accidentally met with in small quantity in other places, some of which shall now be noticed.

Britain.—Excepting in one place, mercury has never been found in this country. About 40 years ago, in digging out the clay for the foundation of a house opposite to the King's Arms Inn, in the street called Hyde Hill, in Berwick upon Tweed, a quantity of native mercury was discovered. The clay being dug out, lay some time in the place to which it was conveyed, and the mercury was observed to exude from the small fissures or cracks which were formed in it as it dried; and within the last three or four years, in making some alteration in the yard of the same house, when the workmen penetrated into the same bed of clay, it appeared to be impregnated with native mercury, which ran out in small globules. The mercury was not deposited in particular veins, but seemed to be distributed through the whole body of the clay *.

It has been said that a small portion of mercury was found some years ago in the island of Islay, on the western coast of Scotland; but this must have proceeded from mistake or fraud, for the nature of the rocks of that island is such as to preclude the hope of discovering any of the ores of that metal; at least they are totally different from the rocks which are its usual repository.

France.—The ores of mercury have been found only in small quantity in France. The silver mine of Allemont in Dauphiné has always afforded a small proportion of mercury combined with silver, or native amalgam, and combined also with cobalt. It is also sometimes, but rarely, met with in the state of cinnabar †. The hill on which the city of Montpellier is built contains native mercury, as well as some other places in its vicinity. The rocks of which it is composed are chiefly a ferruginous sandstone, in a state of decomposition; but the only mine of mercury which has been wrought in France is that of Menildot, in the department of La Manche.

* Commercial Magazine, vol. ii. p. 204.

† Jour. de Phys. 1786.

It was first discovered about 90 years ago. The ore which consists of cinnabar, combined with radiated iron pyrites, and exists also in the state of powder, or native vermilion, is deposited in a kind of potter's clay, running in veins, in a rock of aluminous schistus *.

The mountains in which are situated the mercury mines of the Palatinate, and of the duchy of Deux Ponts, on the left bank of the Rhine, contain a space of 10 or 12 leagues in length from north to south, and 7 or 8 leagues in breadth. The prevailing rocks are a brownish red or gray sandstone, disposed in strata which are nearly horizonta. The mountain of Potzberg is composed of a similar sandstone, which is traversed in all directions by numerous veins of a whitish clay. These veins are nearly in a vertical position, and varying from a few inches to several fathoms in thickness. The mercury is found in these veins in the state of cinnabar, and chiefly in contact with the sides of the vein. The sandstone also which includes the vein is sometimes impregnated with cinnabar, to the distance of several fathoms, and particularly on the upper or hanging side of the vein. It was found in working the principal vein, that its mineral riches were more abundant

* Jour, des Mines. No, vii. p, 31,

towards the surface, than when it reached the depth of about 32 fathoms.

The mountains which surround Landsberg are formed of horizontal strata of sandstone, alternating with a fine grained black limestone and aluminous schistus, with veins of coal. The mountain of Landsberg itself is of a conical form, and consists of a rock described as a hornstone, composed of siliceous earth, alumina, magnesia, and abundance of ferruginous particles. The magnesia is deposited in cavities of the rock. At the base of the mountain, on one side, there is a mass of basaltic rock, and the whole of the strata are in a state of great disorder. The repositories of the mercury are limited to a space of about 550 fathoms long by 300 broad, and are not less irregular than the structure of the mountain. One vein stretches through its whole length, and has been carried to the depth of 80 fathoms, where it assumes a horizontal position, and terminates in the beds of schistus, of which the base of the mountain is formed. This mine of mercury has been wrought for three centuries; and the ores which it affords are chiefly cinnabar, native amalgam, and native mercury.

In the mines of Moerschfeldt, the rocks are composed of sandstone and limestone; the ores are deposited in an indurated clay, and are so rich as to yield one half of their weight of mercury. Petrified fishes are met with in these mines, which are marked all over with spots of cinnabar.

The impression of the fishes is on a blackish slate; from which it may be separated, but they are found to be very brittle, and not thicker than paper.

The mines of the Palatinate, and of the duchy of Deux-Ponts, it is said, produce annually 67,200 lbs. of mercury; and, previous to the year 1794, the whole produce of the mines in the mountains of Potzberg amounted to 467,042 lbs. of mercury.

Spain.—The oldest mine of mercury known is that of Almaden in Spain. According to Pliny, it was wrought 500 years before the vulgar æra, and in his time 10,000 lbs. of cinnabar were transported to Rome, for the purpose of being employed in painting. This celebrated mine is situated in a branch of the Sierra Morena, on the confines of Andalusia, and about 15 leagues to the north of Seville. The hill which contains it is about 1000 fathoms in length, 600 in breadth, and about 120 feet high. It is composed of the same materials as the neighbouring mountains, which consist of sandstone. The surface of the mountain exhibits two inclined planes, which, uniting at the summit, form a crest of rock nearly vertical. This rocky crest, which is entirely bare, is seen spotted with cinnabar, and the village of Almaden is chiefly built on the cinnabar itself.

Two principal veins traverse the mountain lengthwise, and cut it vertically. They are from two to fourteen feet in thickness, and throw out branches in different directions. Towards the middle of the mountain they unite, and form a mass of mineral of 100 feet thick. The vein stones are the same sandstone as that of which the mountain is composed. The finer grained matrix affords the greatest quantity of cinnabar; and the ore is sometimes so rich as to yield ten ounces of mercury from the pound. From other ores only three ounces can be extracted. The sides of the vein are formed of a black slate in a state of decomposition, and frequently containing a good deal of cinnabar, as well as large, round, and flat masses of pyrites, which exhibit internally some spots of cinnabar.

In other parts of the mountain veins of aluminous schistus and iron ore, running in the same direction with the mountain, have been discovered. From these veins are extracted specimens of ore, in which the iron, sulphur, and mercury are closely combined. This fact has been noticed in other mines of mercury; and it shows that these two metals are found in nature in a state of combination, although it cannot be effected by means of art.

Previous to the year 1752, the annual produce of the mines of Almaden was from 5000 to 6000 quintals of mercury, which was exported to Mexico for the purposes of amalgamation, in extracting gold and silver from their ores. About that period, the mercury mines at Guanca Velica, in South America, being nearly exhausted, the mercury required for amalgamation in Peru was carried from Almaden; so that the annual amount of metal extracted from this mine has increased to 16,000 and 18,000 quintals.

Germany.—The celebrated mine of mercury at Idria in Carniola, and on the boundary of the province of Friuli, is situated about eight leagues to the north of Trieste. The small town of Idria, which gives name to the mine, stands in a deep valley, which is surrounded by lofty mountains of limestone. In this valley a dark coloured slate, included between two beds of limestone, is seen rising to the surface at an angle between 45° and 75°. The ores, which are native mercury and cinnabar, are deposited in this schistus, the thickness of which is about 60 feet, and the extent from 200 to 300 fathoms. The position of the metalliferous stratum is variously inclined, sometimes horizontal, and sometimes running in an opposite direction. The depth of the principal shafts, by which the ores are brought up, is about 100 fathoms *.

The colour of the schistus from which the ore is obtained is various. When it is whitish, it is poor in metal; but when it changes to a blackish colour, its metallic riches are increased to about 60 per cent. The metallic bed is sometimes in-

* Ferber's Letters, p. 9.

tersected by vertical strata. When the latter are hard, the ore in a great measure disappears; but when they are softer and more brittle than the metalliferous bed itself, the ore becomes more abundant. In some places, a hard slaty rock is met with, which contains small, shining globules, and yields not more than two per cent. of metal. This is called *coral ore;* and sometimes small veins of coal impregnated with ore make their appearance, and afford about the same proportion of pure metal.

The mines of Idria were discovered in 1497. The mountain in which they were first established is now nearly exhausted; and the operations at present are carried on in an opposite mountain; from which, it is said, as much mercury might be obtained as would answer the demand for that article both in the Old and New World; but for the purpose of keeping up the price, it is added, the quantity extracted annually is limited to 3000 quintals, of which about 100 quintals are native mercury.

Italy.—Near Selvena, in the Siennese territory, cinnabar has been discovered, distributed in irregular masses, and forming thin veins in a clay, mixed with argillaceous marl; but it does not appear to be of much importance.

Transylvania.—There are two mines of mercury at Zalathna in this country. The ore of the first is cinnabar, which is extracted from a vein in a matrix of quartz and lime spar, traversing a black argillaceous slate and sandstone. The ore of the other mine is granulated cinnabar, included in a vein which runs in limestone. The annual produce of these mines does not exceed 6000 pounds of pure quicksilver *.

Asia.—In the whole extent of the Asiatic territory, only one spot is yet known which offers any indications of the ores of mercury. The place alluded to, which is noticed by Patrin †, is about six leagues south-east from Nertchinsk, not far from the frontiers of Chinese Tartary. It is in a small hill of a yellowish marl, intersected with veins of quartz, and interspersed with small masses of the same mineral. The rock itself is penetrated with cinnabar.

America.—The celebrated quicksilver mine of Guanca-Velica in Peru is about 50 leagues to the eastward of Lima, and near the summit of one of the Cordilleras. This mine, which for a period of two centuries afforded annually from 7000 to 8000 quintals of mercury, is now nearly exhausted. According to Helms ‡, the vein of cinnabar was about 80 Spanish ells in extent, and the ore was found partly solid and crystallized

* Born's Travels, p. 120.

† Hist. Nat. vol. iv. p. 322.

‡ Travels, p. 77.

with galena, lime spar, heavy spar, quartz, manganese, arsenic, &c. and partly interspersed in limestone and in fine grained sandstone. The ore, it is said, was wrought to the depth of 600 fathoms, and was succeeded by ores of arsenic, which were taken for cinnabar; and before the mistake was discovered, many hundreds of the workmen perished in the operation of smelting. But the cinnabar at Guanca-Velica is represented by others as being distributed in an immense accumulated mass, without the form of bed or vein; and the space formerly occupied by the ore is a frightful cavity of 150 feet in diameter and 1400 deep. The cinnabar is disseminated in a sandstone similar to that of Almaden in Spain; but the ore is now so poor that fifty quintals do not yield more than six or eight pounds of mercury *.

SECTION IV.

ORES OF SILVER.

Silver is remarkable for its pure white colour, its malleability, and being easily cut with the

* Jour. des Mines, No. 17. p. 79.

knife. The spec. gr. is 10·474. The oxides of silver are easily reduced by the blow-pipe. They communicate to glass an olive colour; and are precipitated from their solution in nitric acid by means of muriatic acid in the form of an insoluble white matter. Silver may be also recognised in its solution in nitric acid by immersing a polished plate of copper; by means of which the silver is reduced, and appears in the metallic state. By these characters, any notable quantity of silver existing in a mineral substance may be detected.

Ores of Silver.—Silver is met with in the metallic state, in that of alloy, in the state of sulphuret, and in that of salt.

Native silver—is not a very uncommon natural production. It possesses almost all the characters of the pure metal, and it is usually in some form either approaching to the cube or arborescent. It is rarely seen in small detached particles, like gold or platina, and it is seldom perfectly pure, being alloyed with gold, copper, iron, &c. When the proportion of gold is considerable, it assumes a yellowish colour, and is then known by the name of *auriferous silver.*

Antimonial Silver Ore—as its name imports, is an alloy of silver and antimony in variable proportions, as of silver 76 to 84, and of antimony 16 to 24; is brittle, of a silvery white colour, sometimes crystallized, and is easily reduced by the blow-pipe, the antimony being driven off.

Arsenical Silver Ore—is a rare mineral of a tin white, or lead gray colour, sometimes crystallized; and is also an alloy of silver 13, iron 44, arsenic 35, and antimony 4.

Vitreous Silver Ore—is one of the most common ores of that metal, is of a lead or steel gray colour, and exists in various forms, sometimes crystallized; composed of silver 75 to 85, sulphur 15 to 25. The sp. gr. is 6·9 to 7·2. A variety, from its brittleness, is denominated *brittle vitreous silver ore*; and is combined with a proportion of antimony, some iron, copper, and arsenic, with some earthy matters.

Red Silver Ore—presents some varieties of colour, arising from the variable proportion of its constituent parts, which are usually silver 56 to 62, antimony 16 to 18, sulphur 11 to 15; and sometimes sulphuric acid, or oxygen. This ore is frequently crystallized. Sp. gr. 5·5.

White Silver Ore—contains a considerable proportion of lead, with some earthy matters, beside the substances of which the former is composed, and therefore may be more properly arranged with lead ores.

Corneous Silver Ore—is a muriate of silver, but contaminated with iron, some earthy matters, and a small portion of sulphuric acid; is often crystallized, has the appearance of horn, and is fusible like wax. Sp. gr. 4·7. A variety of this ore, called *earthy corneous silver ore*, or, according to the fancifully ridiculous German name, of *butter-milk earth*, contains a great proportion of aluminous earth.

Black and sooty Silver Ores—are supposed to be composed of a mixture of the ores already mentioned; some of whose ingredients may have undergone certain changes, from which they derive their peculiar character.

Repositories of Silver.—Silver, though less generally diffused, is more abundant than gold. It is met with in many countries of the world; but while the warmer regions of the earth afford the greatest quantity of gold, the most copious repositories of silver are situated in the colder climates, and either in higher latitudes, or in more elevated regions. The most celebrated silver mines of Europe and Asia are placed between 50° and 60° of north latitude; while those of Peru and Mexico are within the tropics, but in the centre of the Cordilleras, and in regions of eternal snow.

The ores of silver, whatever be their nature, are chiefly met with in primitive rocks, and particularly in those which are arranged in strata. They are not uncommon also in some veins of secondary rocks, but are altogether unknown in alluvial soil. The usual repository of native silver is in veins which traverse granite, gneiss, micaceous and argillaceous schistus, porphyry, and syenite. The other ores of silver are met with in the same kind of rocks, and also in gray wacken syenite and hornblende schistus, and sometimes in limestone.

The matrix of the ores of silver, or the minerals with which it is accompanied, are quartz, agate, flint, hornstone, jasper, serpentine, foliated and compact limestone, fluor spar, and heavy spar. Silver also exists in nature intimately combined with other metallic substances, as lead, copper, mercury, and antimony; and the sulphuret of iron sometimes yields from 2 to 15 per cent. of silver.

Mines of Silver.—The chief mines of silver, as already noticed, are confined to the colder regions of the earth. This is particularly the case with the European silver mines, the most important of which are situated in northern countries.

Britain.—This country, so rich in various other mineral productions, has never possessed any valuable silver mines, properly so called. Some of the lead ores of Britain afford a considerable proportion of silver; but silver ores may be regarded as rare productions of this country. A small quantity of native silver was lately discovered in the mines of Cornwall; and some years ago a vein of silver ore was, for a short time, wrought with great advantage in the parish of Alva, in the county of Stirling in Scotland. The ores were native silver in considerable quantity, it is said, and vitreous silver, or sulphuret of silver. From forty to fifty thousand pounds worth of silver was extracted from the ores before they were exhausted; after which every search to recover the vein proved fruitless; and since that time no silver mines have been wrought in this country. The silver ores at Alva were accompanied with copper, lead, and cobalt ores, with a matrix of lime spar and heavy spar; and it is supposed that the veins traverse rocks of argillaceous porphyry.

France.—The silver mines which have hitherto been discovered in France, do not appear to be of any great importance. The mine of Allemont, 10 leagues from Grenoble, in the department of Isere, is situated near the summit of a lofty mountain. This mountain is composed of beds of gneiss and primitive limestone, which are inclined in different angles to the west. The beds are thin, waved, and twisted, besides being otherwise considerably deranged, by which the richest veins are suddenly cut off. This mountain has been compared, in its component parts and structure, to some of the mountains of Potosi, which contain rich silver mines. The veins are numerous, and run in all directions. The ores are native silver, sulphuret of silver, red silver, and a small quantity of muriate of silver; and they are accompanied by different ores of cobalt, antimony, nickel, &c. The matrix is usually clay mixed with iron, lime spar mixed with asbestus, and some other minerals. The veins were richest at the surface; but as the operations were carried downwards, the produce gradually diminished, so that they are now nearly exhausted. In some other parts of France, indications of silver ore have been observed, as in the Vosges, in the department of the Upper Rhine, where red silver ore is found in a vein of gray copper ore; which latter also contains a certain proportion of silver.

Spain.—The silver mines of Spain are the oldest which are known. They were wrought in the time of the Romans; and it would appear from the remains of the old workings, that the operations were carried on to a great extent. The mine of Guadalcanal, in the Sierra Morena, on the confines of Andalusia and Estremadura, and about 15 leagues to the north of Seville, was formerly very rich. The ore which it yields is red silver, in a matrix of compact carbonate of lime.

Germany.—The mining territory of Freyberg in Saxony abounds with veins of silver, or with lead ores containing a considerable proportion of that metal. The veins which traverse gneiss rocks are generally composed of quartz, lime and fluor spars; and the metallic ores are, argentiferous sulphuret of lead, red silver ore, argentiferous gray copper ore, &c. In the mines of Annaberg, the ore, which according to Klaproth is corneous ore, or muriate of silver, mixed with a great proportion of clay, is imbedded in compact limestone. The mines of Schneeberg in Misnia, and of the Hartz in Hanover, afford chiefly argentiferous galena, which is also sometimes accompanied with the proper ores of silver.

Hungary.—The mines of Schemnitz and Cremnitz in Hungary have been long celebrated, both on account of the richness of their productions, and immense extent of their operations. The rocks which are traversed by these veins are composed of an argillaceous gray stone, mixed with quartz, or schorl, or particles of lime spar. To this rock Baron Born has given the name of *metallic rock*, because it is usually rich in metallic veins. This rock is supposed to be a syenite porphyry, whose base is a fine grained feldspar.

The metallic rock near Schemnitz is described by Baron Born as containing three principal veins. The course of these veins is nearly from north to south, and they run parallel with the river Gran, following even the windings of the channel of that river. The dip or inclination of the veins, excepting some deviations in one of them, is from west to east at an angle of 30 to 70 degrees. In one part of one of the capital veins alluded to, called the *Spitaler* vein, it is joined with an argillaceous white vein, which constantly runs along with it on the hanging side, and from the place of junction the vein is found to contain silver. In the white clay of the hanging fissure are occasionally met with nodules of spar and masses of quartz, which are carefully collected, and yield from four to five ounces of silver per hundred weight.

In this vein Baron Born discovered what he considers as a singular curiosity, and denominates a petrified porpites or simple madrepore, which is included in sound sinople, a mineral resembling red jasper. This petrifaction was found at the depth of 89 fathoms, in a level driven on the vein. The author attempts an explanation of this remarkable phenomenon, by supposing that the animal, whose impression is seen on the stone, may have been produced on a neighbouring hill which lies to the north of Schemnitz, where petrified turbinites and chamites are often found; and while the whole country was covered by the waters of the ocean, may have been carried into the vein at the time it was an open fissure.

The second great vein at Schemnitz exhibits nearly the same general characters as the first, with regard to the distribution and nature of its productions. In the hanging side towards the first vein it contains lead ores; but in the hading side there is a layer of clay from one to four feet, in which are embedded nodules of lead ore, which yield from two to five ounces of silver.

The third great vein at Schemnitz is more irregular in its inclination than the two former, sometimes being nearly perpendicular, and sometimes dipping in a contrary direction from east to west. The ores from this vein are not very rich in silver; but some of them afford a considerable proportion of gold. In proof of the antiquity of the operations in this vein, Baron Born mentions the marks of old works which he observed, and which had been executed before the invention of gunpowder, at least before its application to the blasting of rocks. The ancient method of conducting such operations was by driving wedges of strong dry wood into the fissures or cracks of the rock; and these wedges being moistened with water, swelled and burst the rock by the force of expansion. The same author states, somewhat too credulously, that he discovered in a pit the date of the year 777 cut in the rock; and he asks, "Might I hence draw a consequence for the high "antiquity of this mine?" But there is no attempt to adduce the slightest evidence that the figures might not have been executed at the distance of ten years before, as well as at the distance of many centuries.

Some notion may be formed of the extent of the mining operations at Schemnitz, from the gallery or level called the Emperor Francis' Gallery, by which the whole of the royal mines are drained and cleared of water. This gallery, which forms a very considerable excavation, and is carried through hard rock, is a work of immense labour and difficulty; it is five English miles in length; it was begun in 1748, and finished in 1765.

The mountains round Cremnitz, according to Baron Born, are composed of the same metallic rock already described; but, according to Patrin, they consist of primitive trap. At this place very extensive operations, which were begun at least a thousand years ago, have been established on a large and rich gold vein, and some of its branches. The rock is a white solid quartz, mixed with fine auriferous red and white silver ore, and with auriferous pyrites. At the depth of 160 fathoms the vein continued rich and productive.

Konigsberg is another mining town of Hungary, which is some miles to the north-west of Schemnitz. The valley in which this place is situated, is bounded on one side by metallic rock, and on the other, towards the north, by granite mountains. In the royal mine, at the time it was visited by Baron Born, the vein was observed to run between the metallic rock which formed its hanging side, and the granite which was its hading side. The vein is gray quartz mixed with auriferous pyrites. The first steam, or fire-engine, established in the Lower Hungarian mines, was erected at Konigsberg in 1725, by Isaac Porter, an English engineer, who was then in the Imperial service *,

Bohemia.—The circle of Saaz in Bohemia abounds greatly in various metallic ores, among

* Born's Travels, Letter xx.

which the ores of silver occasionally predominate. The prevailing rocks are gneiss and argillaceous schistus. The veins at Catharinaberg traverse gneiss, and generally run in a north and south direction, and parallel to the mountain in which they are situated. But there are also some powerful veins which cross the mountain. One of this nature is described, which seems to be insensibly blended with the mountain rock. The vein stone is also of the same kind of rock, but occasionally assuming the characters of a variety of granite. It is observed that the vein, which seldom exceeds a foot in width, diminishes in thickness when the containing rocks become harder; and when the sides are found incrusted with a ferruginous clay, it appears to be richer in ores. Fissures from the sides of the vein are found to improve it. A fine white clay, with quartz imbedded in it, indicates rich ore; but a coarse clay, destitute of quartz, especially when it increases in quantity and occupies the whole vein, renders it unproductive or entirely barren. The ores of the vein now described are rich silver and copper pyrites, with fluor spar, blende, various copper ores, and sometimes native silver and copper.

Joachimsthal—a place in the same circle, has been long celebrated on account of its valuable mines. The prevailing rocks are described as gray, micaceous, and quartzose clay slate, which at a great depth became more of an argillaceous nature, soft, foliated, and of a black colour. The mountains around this place have a gentle declivity towards the south, but run in lofty ridges to the east, north, and west, and are intersected by deep valleys. This inequality of surface affords great accommodation to the miners, to open up numerous galleries which converge to the south, and to the valley in which stands the town of Joachimsthal. The whole galleries and works of this district are divided into six different fields, belonging to the same number of companies, and they are drained by two deep drifts or levels; the one of which runs in a direct line 1,600 fathoms; but including its several branches, its whole length is 4,500 fathoms. The depth under the highest tops of the mountain is 170 fathoms. The second great level, which runs through the space of 5,600 fathoms, and in a direct line 1,500 fathoms, is 20 fathoms deeper than the first; but the operations in the mines have been carried to a much greater depth, for at the time in which they were visited by Ferber before 1774, the perpendicular depth under the turf, was from 200 to 350 fathoms, and, excepting the mines in the Tyrol, were then considered as the deepest in the world.

The metallic veins of this mining district are frequently disturbed by dykes of red porphyry, or of trap. These dykes are called by the miners *combs*. The porphyry is described as a red flesh coloured hornstone, in which white particles of feldspar and quartz are inserted. Some large veins of this porphyry cross the metallic mountains, and commonly run from north to south. Sometimes they unite in the veins, run parallel with them, and occasionally increase their metallic riches. The trap dykes, or combs, consist of an indurated ferruginous clay, of a gray, greenish, or black colour. In this latter, white grains of lime spar and greenish schorl are interposed. The course of these dykes, or veins, is very irregular; their thickness is from a few inches to 40 fathoms; they also unite with the metallic veins, run parallel with them, or cross them, and either improve them, render them barren, or disturb their course. It is observed, that the dykes which run from north to south commonly disturb the course of the metallic veins, which they traverse in a contrary direction. A powerful dyke of this description, which crosses one of the principal veins of the district, was discovered on the sole of one of the great levels, where the thickness was not less than from 30 to 40 fathoms. At this place, which is 150 fathoms of perpendicular depth, and about 3000 fathoms distant from the door of the gallery, an entire tree was discovered. At the time of this discovery, it was supposed that this tree was a production of the Antediluvian World. The exterior appearance, the fibrous structure, the concentric circles, the ramification of the substance into round branches, and even the soft unpetrified bark which adhered to them, and something like leaves found in different parts of it, left no doubt with those who had an opportunity of seeing it, that it was a vegetable production converted into stony matter. All this is confirmed by the appearance of the specimens which were then collected, and are still preserved in the cabinets of naturalists. Soon after the discovery was made, that part of the level gave way; and the water increasing, rendered it impossible ever since to examine the spot. The petrifaction was imbedded partly in the slate rocks of which the mountain is composed, and partly in one of the trap dykes which traverse those rocks.

The thickness of the veins varies from one inch to two feet, and the vein stones are a whitish or bluish clay, argillaceous slate, and reddish hornstone, or petrosilex; which latter is the matrix of the richest ores. Rose spar, another vein stone, is a lime spar composed of accumulated, roundish, and twisted lamellæ. The silver ores which are found in this mining district are native silver, which is attached to different vein stones, and assumes various forms; vitreous silver ore, which is dug out sometimes in very large masses, and is considered as a very rich ore, one hundred weight being commonly valued at 180 marks of silver; red silver ore, sometimes beautifully crystallized and transparent, is attached to red hornstone, or rose-formed lime spar; and white silver ore has sometimes, but rarely, appeared.

The silver mines of Berestadt, in the circle of Tabor, are in hills of a gentle declivity, and composed of gray or bluish clay slate, in which appear fissures of greenish lithomarga, or semi-indurated pot stone. These mines were formerly rich in native silver, and other ores of that metal. A vein to the west of this place, which traversed a hard rock, contained reddish coloured feldspar, with galena, blende, and a little silver; but when a joint containing white arsenical pyrites came into the hanging side, the vein produced native silver, vitreous, red, and white silver ore. Another vein in the same place, which is from two inches to one foot in width, is observed to be richest where it is thinnest. It is chiefly enriched by an undulating black clay fissure, which appears sometimes in the hanging side, and then it produces red and white silver ore. When crossed by veins running from east to west, it appears to be cut off and barren, till beyond the place of junction it again becomes productive in its former course. Sometimes the ore and the vein are entirely lost, or hid under the cross joint; fall out extremely rich underneath it, but disappear entirely above it *.

* Ferber's Mineralogical History of Bohemia.

Sweden.—The silver mines of Sahlberg, in Westmania in Sweden, are situated about 28 English miles from Upsal. The ore is an argentiferous galena, in a compact limestone, and it produces a mark, and even a mark and half, of silver in the quintal. The mines have been wrought to the depth of 150 fathoms; the annual average profits amount to about L. 4000, and one eighth of the produce is paid to the king *.

Norway.—The silver mine of Koningsberg in Norway is represented as one of the richest in Europe. The mountains, which are of moderate height, are composed of strata which are nearly vertical, run from north to south, but are a little inclined to the east. They are generally parallel to each other, but sometimes assume a waved or twisted direction. Some of the strata are composed of mica mixed with garnets and lime spar; others consist of a grayish white quartz mixed with a fine black mica, a little carbonate of lime, and reddish hornstone; some are composed of alternate layers of quartz and mica, and others of a ferruginous rock, which in the upper part of the mine is about 33 feet thick, but in the lower part is not more than 6 feet thick.

The veins which cut these strata transversely are from half an inch to 2½ feet in thickness. The

* Ker Porter's Travels.

matrix of the ore is granulated limestone, sometimes foliated, or mixed with fluor spar and oxide of iron. The ores are chiefly native silver, enormous masses of which have been sometimes found, and in particular one is mentioned weighing more than 220 lbs.; sometimes vitreous silver ore; but red silver ore and galena are rare.

It has been observed, that these mines are most productive in that part of the veins where they traverse the strata of ferruginous rock. The greatest depth to which the operations have been carried is about 150 fathoms; and the annual produce, some years ago, was stated at nearly 5000 lbs. of silver.

Asia.—In the northern regions of Asia are situated the silver mines of Zmeof, in that part of the Altaian chain of mountains which lies between the rivers Oby and Irtish, and between 50° and 52° of north latitude. The annual produce of these mines is stated at 60,000 marks of silver, which is alloyed with about 3 per cent. of gold. The mines of Nertschink in Daouria, and near the river Amour, yield argentiferous galena, producing annually about 30,000 marks of silver, and containing about 1½ per cent. of gold *. Patrin supposes that there are silver mines in some parts of the Chinese territories, from the circumstance of

* Patrin, Hist. Nat. des Miner. v. p. 141.

the Russian merchants who trade to China returning from that country with small masses of silver, from several ounces to a pound weight, which they receive in exchange for their commodities.

America.—But the ores of silver are distributed with far greater profusion in the elevated regions of the New World. The silver obtained from Mexico and Peru alone is supposed to be ten times as much as the whole produce of the ancient continent.

The celebrated mines of Potosi in Peru, which were discovered in 1545, are situated in an insulated mountain, which is 18 miles in circumference, and rises to an immense height in the form of a sugar loaf. This mountain, which is about 100 leagues from the South Sea, and near the sources of the river Plata, is chiefly composed of a yellow, very firm, argillaceous slate, and is full of veins which traverse the mountain in all directions. These veins are filled with ferruginous quartz, which constitutes the matrix of very rich silver ores. These are chiefly native silver and vitreous silver ore, the latter of which, on the first discovery of the mine, yielded about half its weight of pure silver. The produce is now less than formerly, but is still very considerable *.

* Helm's Travels, p. 43.

About six miles from Pasco is the mountain Jauricocha, which is distinguished by the name of *silver mountain*, from the great abundance of silver ores with which it is stored. This mountain, which is about half a mile in diameter, and only 15 fathoms in depth, is composed of a fine porous brown iron stone, which throughout its whole extent is interspersed with pure silver. The produce of the iron stone itself does not exceed 9 marks of silver from every 50 cwt.; but a friable, white, metallic clay, which is met with in the middle of the mass of ore, and is about 9 or 10 inches in thickness, yields from 200 to 1000 marks of fine silver in every 50 cwt. The mountain is penetrated in all directions, without any order or attention to security; so that it is supposed the whole may in the course of a few years fall in. About 200 private proprietors and workers of mines have their pits on this mountain, and extract annually 200,000 marks of silver *.

The Mexican mines are richer and more numerous than those of Peru. The mine of Valenciana, in the intendancy of Guanaxuto, is in a vein of the enormous thickness of 40 fathoms. This immense vein traverses a mountain of argillaceous schistus. The vein stones are quartz, hornstone, lime spar, argillaceous schistus, and stea-

* Helm's Travels, p. 96.

tites; and the ores are iron pyrites, galena, and blende, with native, vitreous, and red silver ores. The mine is wrought at the depth of 328 fathoms. There is another vein in the vicinity of the former, which has not yet been wrought, but which promises to yield as much silver as all the mines of New Spain. A mine in the intendancy of St Louis of Potosi is wrought at the same depth; and another near Patchuca, in the intendancy of Mexico, is less powerful than the great vein at Valenciana, but is not less productive.

The whole produce of the Spanish silver mines in South America amounted, in the year 1790, to L. 5,079,183 Sterling. This is the quantity of silver coined in the royal mints, and is exclusive of that which is fabricated into various utensils for churches, convents, and private persons *.

SECTION V.

ORES OF COPPER.

Copper is one of the most useful of the metals, on account of its tenacity, ductility, and mallea-

* Helm's Travels, p. 141.

bility, as well as on account of the numerous alloys and combinations which it forms with other metals, and which render it susceptible of being applied to many of the most important purposes of life. Its specific gravity, after fusion, is 7·788.

Copper may be detected in its ores by dissolving a small portion in nitric acid, and immersing in the solution a polished plate of iron. The copper is thus precipitated by the iron in the metallic state; or by digesting some of the ore in a solution of ammonia or volatile alkali, if it contain any copper, the solution assumes a beautiful blue colour.

Ores of Copper.—Copper exists in nature in all the different states of metallic ores. It is found in the state of native copper, in that of alloy, in the state of sulphuret, in that of oxide, and also in the state of salt.

Native copper is no uncommon production, as it is met with in many copper mines along with its other ores. It assumes various forms, and is sometimes crystallized. Sp. gr. 7·72 to 8·58.

Vitreous copper ore is of a lead gray or yellowish colour, is rarely crystallized, and is soft and brittle. Sp. gr. 4·81 to 5·33. It is composed of copper 78·5, sulphur 18·5, iron 2·25, with a small portion of silica. Some varieties contain $\frac{1}{4}$th of iron.

Variegated copper ore usually exhibits a great variety of colours, is sometimes crystallized, and is composed of copper 6·3 to 6·8, iron 12 to 18, sulphur 19, and oxygen 5.

Copper pyrites is usually of a yellowish colour, but sometimes steel gray; is often crystallized. Sp. gr. 4·08 to 4·3. It is composed of sulphur, copper, and iron, in variable proportions; and sometimes contains a mixture of gold and silver.

White copper ore is between a silvery white and brass yellow colour. Sp. gr. 4·5. Gives out before the blow-pipe a white fume, with the odour of arsenic, and is supposed to be a compound of copper, iron, arsenic, and sulphur.

Gray copper ore is of a steel gray colour, of various shades, often crystallized. Sp. gr. 4·4 to 4·8. Is composed of copper 16, sulphur 10, antimony 16, silver 2, iron 13, with a small proportion of earthy matter, as silica and alumina, and sometimes with a large proportion of lead.

Black copper ore exists in the state of powder, of a brownish black or deep brown colour. It is supposed to be a sulphuret of copper, and yields sometimes from 40 to 50 per cent. of metal.

Red copper ore is found in a compact, foliated, or capillary form, of a cochineal or carmine red colour; sometimes crystallized; and the crystals are semi-transparent. This ore is supposed to be an oxide of copper, but was formerly conjectured to be a carbonate. It is easily reduced before the blow-pipe, and is entirely soluble in muriatic acid.

Brick-red copper ore exists either in an earthy or indurated form, is of a brownish red, or reddish brown colour, and is supposed to be a mixture of red copper ore, or oxide of copper and brown oxide of iron, in variable proportions.

Emerald copper ore is a beautiful mineral, of an emerald green colour, is semi-transparent. Sp. gr. 3·3. Is composed of oxide of copper 28·5, silica 28·5, carbonate of lime 43.

Azure copper ore, or carbonate of copper, is either in an earthy or indurated and radiated form, the latter being sometimes crystallized. The colour is sky-blue, light azure, or indigo blue. Sp. gr. 3·4 to 3·6. The constituent parts are copper 66, carbonic acid 18, oxygen 8, water 2. The earthy variety is sometimes found in superficial layers on sandstone, and sometimes the whole sandstone is impregnated with the earthy carbonate of copper.

Malachite, or green carbonate of copper, is distinguished into two varieties, the fibrous and compact; the first composed of capillary crystals grouped together, and exhibiting a silky appearance; and the second in a globular or stalactitical form. The colour is emerald, apple, or blackish green. Sp. gr. 3·5 to 3·6. It is composed of copper 58, carbonic acid 18, oxygen 12·5, and water 11·5.

The compact variety of malachite is frequently susceptible of a fine polish, which, with its beautiful and delicate colours, has brought it into high estimation for various ornamental purposes. The most splendid specimen of compact malachite yet known adorns the cabinet of Dr Guthrie at St Petersburgh. It is 32 inches long, 17 broad, and 2 inches thick. According to the account of Patrin, who describes it, this splendid mass is estimated at 20,000 franks, which is more than L. 800 Sterling. If I am not misinformed, it was once offered to sale in Britain; but as no purchaser appeared, it was carried back to Russia.

Green copper ore, or earthy carbonate of copper, is of a verdigris or emerald green colour; and is supposed to be a mixture of carbonate of copper, with some oxide of copper and alumina and lime.

Ferruginous green copper ore is either in an earthy or slaggy form, of an olive green colour, and is supposed to be a mixture of carbonate or oxide of copper, with iron ochre in variable proportions.

Micaceous copper ore, or arseniate of copper, is either in a foliated or lenticular form, is frequently crystallized, and is of an olive green or sky blue colour. Sp. gr. 2·5 to 2·8; and the constituent parts are oxide of copper 39, arsenic acid 43, water 17. Some arseniates of copper contain a considerable proportion of oxide of iron with some siliceous earth.

Green sand of Peru, or muriate of copper, is crystallized, and of an emerald or leek green colour. Sp. gr. 3·5 to 4·4. Constituent parts, oxide of copper 70 to 76, muriatic acid 10 to 11, water 12 to 18.

Phosphate of copper is met with crystallized; is of a grayish black, but internally of an emerald green colour. Constituent parts are oxide of copper 68, phosphoric acid 31.

Repositories of Copper Ores.—Most of the ores of copper are met with in primitive rocks; and some of the ores, particularly native copper, some of the sulphurets of copper and gray copper ore, exist only in rocks of that class. The repository of the phosphate, arseniates, and muriate of copper, whose natural history is hitherto imperfectly known, is also of the same nature.

The ores of copper seem to be more abundant in rocks which are disposed in beds, such as gneiss, schistus, &c. than in those in a massive form, as granite and porphyry. Some amygdaloids, with a basis of trap, contain some of the ores of copper, as the oxide, and even native copper; such as the amygdaloid of Oberstein, mentioned by Saintfond, which includes agates and prehnite impregnated with copper.

The ores of copper are generally distributed in veins, or constitute a part of other veins, composed of stony matter and other metallic ores. They are sometimes, however, found in beds or large masses. The carbonates of copper, and particularly malachite, exist in all classes of rocks, and sometimes even in alluvial soil. Even bones and fossil wood are sometimes penetrated with these ores. Limestone also sometimes forms a considerable repository for the ores of copper. The Ecton copper mine on the borders of Derbyshire, is in a rock of that nature.

Mines of Copper.—Copper is one of the metallic substances which is universally distributed over the globe, and in many countries it is found in great abundance.

Britain.—Some very valuable copper mines have been long wrought in this country. In Cornwall, the mines of copper are in veins which traverse the granite of that country. They frequently accompany the tin veins, and run in the same direction, which is generally from east to west, and are nearly in a vertical position. Some of the veins are from four to five feet in thickness; and from 300 to 400 and 600 feet in depth, they continue to be equally productive.

It has been remarked, that in the veins of tin and copper, which frequently run parallel to each other, when the ore of the one is abundant, that of the other is more sparingly deposited. It has been observed, too, that the ores of tin are generally near the surface, and are rarely worth working beyond the depth of 50 fathoms; while the greatest quantity of copper ore is met with from that depth downwards to 100 fathoms *.

The copper ores of Cornwall are chiefly yellow ore, or copper pyrites and vitreous copper ore; and they are usually accompanied with other metallic ores, as those of lead, zinc, and cobalt; and with fluor spar, lime spar, barytes, and quartz. Native copper is also no uncommon production; and it is generally deposited in that part of the vein which is nearest to the surface, and is the least rich in other ores. Sometimes, however, it is met with at a considerable depth, as in Cook's kitchen mine, which yielded several tons of copper fit for immediate fusion †. The mines of Cornwall also occasionally afford malachite, with many varieties of the arseniates of copper.

The produce of the copper mines of Cornwall, as it is given by Pryce ‡, from 1726 to 1735, including a period of 10 years, was 64,800 tons of ore, which was sold at the average price of L. 7 : 15 : 10 per ton, and the amount was L. 473,500. From 1766 to 1775, the quantity of ore was 264,273 tons, which was sold at the average price of L. 6 : 14 : 6, and brought L. 1,778,337.

* Pryce, Mineralog. Cornub. p. 8. Introduct.

† Ibid. p. 61.

‡ Ibid.

The Ecton mine, which lies on the borders of Derbyshire and Staffordshire, is one of the most remarkable copper mines in the kingdom. It is situated in a dark brown stratified limestone, the beds of which are greatly deranged. The ore is deposited in a large accumulated mass, which is called by the Germans *Stockwerk*. It is supposed that this mine was wrought at a very early period. At one time about 1000 persons were employed in the works, and then it afforded an immense produce of rich ore. The operations are now carried on at the extraordinary depth of 220 fathoms.

The most common ore is yellow copper ore, which is accompanied with galena and blende, and with calcareous spar, sometimes in fine rhomboidal crystals, fluor spar, and barytes *.

Copper ores are found in considerable abundance in different parts of Wales; but the greatest quantity is obtained from Pary's mountain, in the island of Anglesey. Pary's mountain is about a mile in length, and it is the property of Lord Uxbridge and the reverend Mr Hughes. The discovery of copper ore in this place was made between 30 and 40 years ago, and it has proved a most beneficial concern to the proprietors. The body of the mountain is composed chiefly of copper ore; so that it is to be considered as a large

* Mawe's Mineral. of Derbyshire, p. 109.

accumulated mass or stockwerk of ore: and from the peculiar mode in which the mineral is deposited, the operations are carried on very differently from those of other mines; for there are comparatively few shafts or levels, because the greater part is dug out in the manner of an open quarry. Two of these quarries or mines, belonging to different companies, are carried on; the one is known by the name of the Mona mine, and is the sole property of Lord Uxbridge; the other, which is called the Pary's mine, is the joint property of Lord Uxbridge and Mr Hughes*. "The view," says Mr Aikin, "down this steep and extensive hollow, is singularly striking. The sides are chiefly of a deep yellow, or dusky slate colour; streaked, however, here and there by fine veins of blue or green shooting across the cavern, mingled with seams of grayish yellow. The bottom of the pit is by no means regular, but exhibits large and deep burrows in various parts, where a richer vein has been followed in preference to the rest. Every corner of this vast excavation resounds with the noise of pick-axes and hammers; the edges are lined with workmen drawing up the ore from below; and, at short intervals, is heard from different quarters the loud explosion of the gunpowder, by which the rock

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* Aikin's Tour, p. 134.

is blasted, reverberated in pealing echoes from every side *."

The rock of which the mountain is composed is an aluminous schistus; but this constitutes a small proportion of the whole mass, forming as it were only an external covering to the ore which it contains. The matrix of the ore is described as a black gray chert.

The ores which are obtained from this mine are native copper, but in very small quantity; black ore, which contains copper mixed with galena, calamine, and a little silver; malachite, or green and blue carbonate of copper; and the most abundant of all, yellow sulphureted ore, of which the richest yields about 25 *per cent.* of copper. Some of this ore is so poor as to afford only 1¼ *per cent.* of copper; but this kind is wrought rather for the purpose of extracting the sulphur than the copper.

The ore is got from the mine by blasting. It is then broken into small pieces by means of the hammer, an operation chiefly performed by women and children; and piled into a kiln, to which is attached by means of flues, a long sulphur chamber. The kiln is covered close; a little fire is applied in different places; the whole mass gradually

* Aikin's Tour, p. 135.

kindles, and the sulphur sublimes to the top of the kiln, from which it is conveyed by the flues to the chamber. This process is continued for six months, at the end of which the ore is fully roasted, and during that time the sulphur chamber is cleaned four times.

But the sulphate of copper, which is found in solution at the bottom of the mine, and contains about 50 per cent. of pure metal, affords a greater produce than any of the other ores. This solution is pumped up into cisterns about two feet deep. Of these cisterns there are many ranges, each of which communicates with a shallow pool of considerable extent. Cast iron plates and damaged iron vessels are introduced into the solution in the cisterns, when the sulphuric acid enters into combination with the iron, and the copper is precipitated in the form of a red sediment, and nearly in the metallic state. The cisterns are let off four times in the year, when the sulphate of iron in solution is let off into the hollow pool, and the copper is taken to a kiln, where it is well dried, and is then ready for exportation.

The greatest depth of the mine is about 50 fathoms; at that depth the ore is equally abundant, and is supposed to be superior in quality to that which was found nearer the surface. The number of men employed at the two mines, including the smelters, is about 1300, and it is supposed that the annual quantity of ore obtained from both mines is from 50,000 to 80,000 tons *.

Scotland.—Ores of copper are occasionally found in the lead mines in different places of Scotland; but sometimes they have been met with in such abundance, as to constitute the predominant ore. Such, for instance, was the copper mine at Aithrey, in the Ochil hills, north-east from Stirling. The ore obtained from that mine was chiefly gray copper ore. Some years ago copper was extracted from the sandstone rocks in the neighbourhood of Gourock, on the western coast of Scotland. The ore is in the state of carbonate, and disseminated not only in fissures, but sometimes through the whole substance of the rock. The existence of copper ore in the neighbourhood of the village of Currie, about five miles west from Edinburgh has been already noticed by the author. This ore is said to be deposited in limestone. A specimen from that place was lately put into my hands for examination. The ore seems to be in the same state with that of the copper ore from Gourock; but I have not yet been able to obtain any precise information with regard to its geological history.

At Sandlodge in Shetland, a copper mine was wrought in the year 1803. The rock containing the mine or vein is sandstone, which at the depth

* Aikin's Tour, p. 140.

of 22 fathoms is succeeded by what is described as a petrosiliceous or quartzy rock, which is traversed by numerous veins of brown quartz. The principal vein is said to lie between the sandstone and the quartzy rock, in a direction from north-east to south-west, from which it would appear that the ore is deposited in the form of a bed, rather than in that of a vein. Beside various iron ores, the copper ores which have been obtained from this mine are chiefly carbonate of copper, of a rich green colour, in a friable and amorphous form, and beautiful fibrous malachite, which is imbedded in iron ore; sulphuret of copper, or copper pyrites, which is sometimes disseminated in feldspar, and sometimes in large masses of iron ore. The fine specimens of malachite were found near the bottom of the mine. An expenditure of nearly L. 10,000 Sterling, was incurred in forming a mining establishment at this place; but as the operations proved unsuccessful, they have been since abandoned. The hills in the neighbourhood of this place afford copper pyrites in considerable quantity, and at Conningsburgh cliffs a vein of that ore was wrought a few years ago; but that too has failed, from the scarcity of ore, and at this moment I do not know of a single copper mine in Scotland which is in a state of active operation*.

* Trail, Nichol. Jour. xv. p. 364.

Ireland.—There are extensive copper mines at Cronebane and Ballymurtagh, in the county of Wicklow in Ireland. At the latter place the mines were opened more than half a century ago. The mountains containing the veins are composed of argillaceous schistus, and the ore is chiefly copper pyrites, which yields from 7 to 10 per cent. of copper.

The greater proportion of the ore, after being separated from the matrix, is roasted and smelted in the usual way, but a good deal of it is exposed to the atmosphere, and with the aid of moisture the sulphur is converted into sulphuric acid, thus forming a sulphate of copper. This process is greatly promoted by applying heat. The sulphate of copper is decomposed by means of iron, as described above, and the copper is obtained in the metallic state. The Cronbane mines exported in 1800 above 1800 tons of ore *.

Copper ore has been discovered, and it is said from the indications, in considerable quantity, in various other places of Ireland, as in the hill of Allen, in the hills of Kilmurry in the county of Kildare; similar appearances have been observed in the Queen's county, as well as in the counties of Waterford, of Tipperary, where green mala-

* Fraser's Survey of Wicklow p. 14.

chite has been met with in great quantities; in the county of Cork, and some other places *.

France.—It does not appear that the copper mines of France are of any great importance. The mines of Baigorry in the western Pyrenees, afforded annually 2500 quintals of copper previous to the year 1770, but they are now nearly exhausted. There are some copper mines in Languedoc, but the most valuable are those of Chessy and St Bel near Lyons, whose annual produce is about 3000 quintals of copper. The ore found at the latter place is chiefly copper pyrites, which is so poor as to yield only about 3 per cent. It is extracted from a powerful vein, which traverses a rock, approaching to the nature of steatites †.

Spain.—The copper mines of Spain are not more important than those of France. They are situated on the frontiers of Portugal. The ore is copper pyrites, which exists in a vein of 160 feet thick, but it does not afford more than 4 or 6 *per cent.* of copper, and the whole produce is not more than from 200 to 300 quintals of copper; but part of the vein only near the surface has been opened. This mine, according to the tradition of the country, was wrought in the time of the Car-

* Fraser's Gleanings in Ireland, p. 16.

† Brongniart's Mineralogie, tome ii. p. 231.

thaginians *. Other mines have been wrought in different places of Spain in former times, but they are now either exhausted or neglected.

Germany.—Germany contains some valuable mines of copper; in particular, the mines of Hessia are remarkable on account of the ore being deposited in a bituminous stratum of marl schistus. This stratum is not more than from four to eight inches thick, but it is of great extent. It is found at the depth of 200 feet, and is covered by the following strata.

Vegetable earth from -	6 to 12 feet
Whitish limestone -	36 to 48
Blue clay with gypsum -	48 to 60
Blue limestone - -	48 to 54
Beds of gypsum mixed with beds of clay - - -	42 to 48
Swinestone - -	6 to 9
Limestone - -	12 to 21
Aluminous schistus with iron pyrites	2
Bed of copper ore -	4 to 8 inches.

The ore contained in this bed is chiefly copper pyrites, but sometimes vitreous copper ore and red oxide of copper appear. The schistus containing the copper pyrites is frequently marked with the impressions of fishes, and it has been

* Jour. des Mines. No. xxxix. p. 400.

observed that the ore becomes richer as the impressions become more numerous. Similar impressions are also observed in the pyritous schistus which forms the covering of the copper ore, and sometimes, but rarely, in the bed of limestone which is below it. Under the copper schistus there is a small stratum of sand of two inches in thickness, which is equally impregnated with copper. A reddish sandstone approaching to a kind of pudding stone next succeeds, which serves as a base for the other strata. The thickness of this last stratum is unknown.

The bearing or course of the strata now described is from east to west, and the inclination, which is about a fathom in 8 or 10, is to the south. These strata are intersected by veins containing only heavy spar, quartz, and lime spar, excepting a few which yield cobalt at a considerable depth.

The copper schistus does not yield more than from 2 to 3 *per cent.* of copper, but it is said to be peculiarly useful in the manufacture of brass.

The most considerable of the mines of Hessia is that of Riegelsdorff, which yields annually 2500 quintals of copper.

There are similar mines of copper at Frankenberg near Cassel, and at Bieber in Hanau, as well as at Eisleben in the county of Mansfeld, and in the duchy of Magdeburg.

Hungary.—There are some valuable copper mines in Hungary, and particularly those of

Herengrund near Neusohl. The mineral is in the form of gray copper ore, which is deposited in beds of considerable thickness, in a breccia of micaceous schistus.

Sweden.—One of the most extensive, and one of the most productive copper mines in the world, is at Fahlun, in the province of Dalecarlia in Sweden. This mining district, which is included in a space of 9 leagues in length by 2½ in breadth, is surrounded by a reddish granite, which becomes of a finer grain as it approaches the centre of the space now described, and is then succeeded by a micaceous rock, which divides into rhomboidal fragments.

The mine itself is comprehended within a space of 1200 feet long by 700 broad, and consists of an enormous mass of iron and copper pyrites, lying in a vertical position from north-west to south-east, which is the direction of the valley in which it is deposited. The ore is in immediate contact with a schistose steatites, which may be taken for the hanging or ledger side indifferently. The copper pyrites occupies the sides of the vein, and in the middle of the mass is the iron pyrites. This central part, however, is sometimes filled by veins of the rock itself. To the west of the principal vein, three other veins are wrought, which, as they are separated only by thin partitions of the micaceous rock, may be regarded as one. They are remarkable on account of their position, by describing a semicircle, and embracing the large masses of ore.

On the principal vein there is an immense opening, which is not less than 840 feet long by 720 broad, and 240 deep. This frightful gulf was produced in the year 1687, by the works falling in, in consequence of the subterraneous operations having been improperly conducted.

This celebrated mine was lately visited by an English traveller *, who describes the mass of ore as lying in the form of an inverted cone, and the excavation, according to this account, has been carried to the depth of 200 fathoms; and it is supposed that this is nearly the utmost extent of the mass of ore, as the operations begin to be more limited. Five hundred persons are employed in this mine, the ore from which, it is said, produces the best copper in Europe. In this mine the celebrated Gustavus Vasa, king of Sweden, when driven from his throne, worked for some time, to procure the means of subsistence.

In the mine of Garpenberg, which is about 18 leagues from Fahlun, there are no fewer than 14 veins in a vertical position, and all parallel to each other. They are situated in a quartzose micaceous schistus, which is also disposed parallel to the veins,

* Ker Porter.

This circumstance shows that these veins are to be considered as vertical strata, and not true veins, which traverse other rocks *.

Asia.—In Siberia there are two principal copper mines, and they are both situated in the extensive chain of the Uralian mountains. One of these mines called Goumechefski, is about 14 leagues to the south-west of Catharineburgh, and in the central part of the chain. This celebrated mine is in a kind of plain on the border of a lake, which is entirely surrounded by primitive mountains. The vein is nearly in a vertical position, and arranged between a bed of white primitive marble from five to six fathoms thick, and an argillaceous schistus nearly in a state of decomposition. The matrix of the ore is a clay of different colours, and the ores consist chiefly of native copper in grains and in small masses, with some vitreous copper ore; and the fissures and cavities are encrusted with malachite. It is from this mine that the splendid specimens of the latter variety of copper ore, which adorn the cabinets of mineralogists, are obtained. It is observed that the ore is not found at a greater depth than from 20 to 25 fathoms, and it is usually richest on that side of the vein which is nearest to the limestone or marble. The length of this vein is about 200 fathoms, and its thickness va-

* Patrin, Miner. vol. v. p. 87.

ries from one to ten fathoms. The produce of copper is only about 3 or 4 *per cent.* but the annual amount is 4000 quintals of metal.

The other mines of Siberia are those of Tourinski on the river Touria, above 100 leagues to the north of Catharineburgh. They are situated on the eastern base of the Uralian chain. The rocks of which the hills are composed consist of a brittle hornstone porphyry, of an olive colour. This porphyry reposes on argillaceous schistus, on which lies a thick bed of white marble, and nearly in a vertical position. The vein is included in the latter rock, the thickness does not exceed 4 fathoms, and it is from 20 to 25 in depth. One side of the vein is encrusted with a brownish coloured ochre, and on the other is a yellowish indurated clay, in which are deposited beautiful specimens of native copper in a dendritical form, the branches sometimes penetrating the marble itself, or entirely imbedded in that rock.

The matrix of the ore in these mines is clay, like that of the former, but is much richer, and often exhibits a beautiful appearance, being varied with veins of blue and green steatites, red oxide of copper, with fragments of the different varieties of malachite, large masses of gray copper ore, and not unfrequently native copper. The ore yields from 18 to 20 *per cent.* and the annual produce is 20,000 quintals of copper.

Other parts of the Siberian territory yield copper in considerable quantity, and particularly on the western side of the Uralian mountains, where there is an immense deposition of clay and sand, mixed with the remains of vegetables and green and blue oxides of copper. It has been conjectured that this immense deposition was produced by the great currents of the ocean from east to west, carrying with them the rubbish from the copper veins in the east. Trunks of the palm tree and of the bamboo, and sometimes even entire trees, which have been converted into copper ores, are found among this sand *.

Ores of copper, and particularly native copper, are also met with in the peninsula of Kamtschatka. Japan, it would appear, contains valuable mines of copper. It is met with in China, and in Borneo, Formosa, Timor; and in other islands of the Indian Archipelago, copper is by no means a rare production.

Africa.—Mines of copper have been discovered in various parts of the extensive continent of Africa, as in the kingdom of Morocco, Abyssinia, &c.; and, according to Mr Barrow, it is not uncommon in the mountains to the north of the Cape of Good Hope, in the country of the Namaquas, on the western coast of Southern Africa. The

* Patrin, vol. v. p. 97.

ore is copper pyrites, which is supposed to be rich and easily reduced, as the natives are acquainted with the art of extracting the metal *.

America.—The copper mines of South America are uncommonly rich, and it is supposed far exceed those of Europe. The richest are in the province of Coquimbo in Chili, and they afford masses of native copper of immense size. Copper ores are also abundant in Peru and Mexico, and those which are most common are gray copper ore, azure copper ore, and malachite.

In North America, masses of native copper are frequently met with near Hudson's Bay. These are directly converted, by means of the forge, to domestic purposes.

SECT. VI.

ORES OF IRON.

Iron, which is one of the most useful, is also one of the most abundant of the metals. It is at the same time universally diffused. With the ex-

* Travels, vol. i.

ception of native iron, this metal exists in all the different states in which metallic ores are found.

Ores of Iron.—Native iron has been excepted from the ores of that metal, because its existence as a terrestrial production still remains doubtful. The instances of the discovery of native iron, which have been fully established, are those of an immense mass, which was found by Pallas in Siberia, and which amounted to no less than 1680 lbs. or 15 cwt.; another of 3 cwt. which was discovered by Rubin de Celis in South America; and some others of smaller magnitude mentioned by Humboldt. But as these masses very nearly correspond with the substances which are certainly known to have fallen from the atmosphere, in the nature and proportions of their constituent parts, it is supposed, and with much probability, that they have had a similar origin.

The fact of the descent of meteoric stones from the atmosphere rests on the most indubitable evidence, which has been furnished by the records of history from a period of 600 years before the Christian æra, and by the testimony of living witnesses in almost every country of the world, who have had ocular proof of the phenomena. The constituent parts of native iron are found to be, according to Klaproth, who examined a specimen of the mass from Siberia, from 96½ to 98½ of iron, and 1½ to 3½ of nickel; and the constituent parts of some meteoric stones which fell in France are stated to be silica 54, oxidated iron 36, magnesia 9, nickel 3, sulphur 2, and lime 1; and, according to the analysis of others, a small proportion of chromium.

Various opinions have been held concerning the origin and formation of meteoric stones. According to some, they have been ejected from volcanoes on the earth; and according to others, from lunar volcanoes, with such a degree of force as to overcome the power of gravitation towards the moon, and thus be carried towards the earth. Some ascribe their origin to those meteors which exist in the atmosphere, and suppose that they are produced from the gaseous elements of the substances of which they are composed. But a more extraordinary opinion has been started by others, that they are fragments of a planet which has burst in consequence of some tremendous explosion. These opinions, it is obvious, are mere conjectures, and the difficulty yet remains unsolved, to account in a satisfactory manner for the origin of meteoric stones.

Iron pyrites exhibits many varieties of form and colour. Sometimes it is radiated, sometimes capillary or acicular, and sometimes crystallized. The colour is bronze yellow, golden yellow, or steel gray; sp. gr. 4·6 to 4·8; and the constituent parts sulphur 52·5, iron 47·5. Some varieties contain a small portion of gold, and others a portion of arsenic.

Magnetic pyrites is of a copper red or bronze yellow colour, and contains a greater proportion of iron, by which it is attracted by the magnet. The constituent parts are iron 63·5, sulphur 36·5.

Magnetic iron ore is so denominated, because it attracts the magnetic needle, and even iron filings. Sometimes it is in a compact form, when it is denominated a natural magnet, and sometimes in small grains like sand. Sp. gr. 4·2 to 4·9; and the constituent parts are supposed to be iron 80 to 90, oxygen 10 to 20.

Specular iron ore exists either in masses or crystallized, of a steel gray, bluish or reddish colour, sometimes tarnished and iridescent. Sp. gr. 4·7 to 5·2. This ore affects the magnetic needle, but does not attract iron filings. It is supposed to be an oxide of iron containing from 60 to 80 *per cent.* of metal.

Red iron ore includes several varieties, as red iron froth, compact red iron ore, red hæmatites, and red ochre. The constituent parts are oxide of iron from 60 to 70, silica from 4 to 20, with a portion of alumina and manganese.

Brown iron ore includes similar varieties with the preceding species, and probably differs from it only in the proportion of its constituent parts.

Sparry iron ore exists either massive or crystallized, of a yellowish gray, or grayish white colour. Sp. gr. 3·6 to 4, and its constituent parts are supposed to be equal parts of carbonate of lime and of iron, with $\frac{1}{4}$th of manganese.

Black iron ore contains two varieties, compact black iron ore and black hæmatites. The colour is steel gray or bluish black, and it is supposed that it contains a larger portion of manganese, with alumina and lime, than some of the other ores of iron.

Argillaceous iron stone comprehends several varieties, as red chalk, which is of a dark or blood red colour; columnar iron stone, of the same colour, or brownish red; granular iron stone; common iron stone; kidney-form iron stone in a nodular form, and known by the name of eagle stone; and pisiform iron ore, which is in small spherical or flattened particles, and of a brownish red colour. The constituent parts of the varieties now enumerated are from 30 to 60 of iron, with a variable proportion of oxygen, alumina, silica, and water.

Bog iron ore also includes several varieties, denominated morassy, swampy, or meadow iron ore, according to their repository. These varieties exist in the form of earthy, amorphous, tuberculated or corroded masses, and are of a blackish or yellowish brown colour. The constituent parts are oxide of iron combined with the phosphate of iron, and alumina and silica.

Blue and green earthy iron ore is so denominated from its colour, is in a friable form, and was supposed to be a native Prussian blue; but according to a late analysis, it is composed of phosphate of iron with aluminous earth.

Phosphate of iron is met with in the form of rounded pieces, composed of capillary crystals; the colour bluish, from a blue powder coating the crystals. Sp. gr. 2·5 to 2·6. Constituent parts are oxide of iron 42, phosphoric acid 27, silica 3, alumina 5, lime 9, water 13.

Pitchy iron ore, or phosphate of iron, is of a reddish brown or black colour. Sp. gr. 3.9. Constituent parts, oxide of iron 31, oxide of manganese 42, phosphoric acid 27.

Arseniate of iron is of an olive green, yellow, or brown colour, and is crystallized in the form of small cubes, which are grouped together. Sp. gr. 3. Constituent parts, oxide of iron 48, arsenic acid 18, lime 2, water 32.

Arseniate of iron and copper is crystallized in four-sided rhomboidal prisms, colour bluish white, crystals semitransparent. Sp. gr. 3·4. Constituent parts, oxide of iron 27·5, oxide of copper 22·5, arsenic acid 33·5, silica 3, and water 12.

Chromate of iron is of a grayish or blackish brown colour. Sp. gr. 4·03. Infusible before the blow-pipe, but melts with borax, and imparts a beautiful green colour. Constituent parts are oxide of iron 35, chromic acid 43, alumina 20, and silica 2.

Repositories of Iron Ores.—The great abundance and universal diffusion of iron have been already noticed. It exists in every kind of soil, and in every kind of rock, in a smaller or greater proportion, and it is met with in every region of the earth: But it has been observed, that the black or deep brown oxides of iron, or the ores of iron which contain a large proportion of metal, combined with a small proportion of oxygen, belong exclusively to primitive rocks, and constitute an integrant part of these rocks. On the other hand, the ores of iron which are composed of the red oxide, have their repository among the secondary rocks. If such ores are met with among the primitive rocks, they exist in veins, and do not form a constituent part of these rocks, as in the case of the black oxides.

The ores of iron might perhaps admit of a natural division into iron ores, properly so called, in which the proportion of iron is great, with very little extraneous matter, and iron stones, which contain a large proportion of earthy matter, and exhibit more of an earthy than of a metallic appearance. According to this division, it might be said that the primitive, and some of the secondary rocks, are the chief repositories of iron ores, and that the iron stones exist solely among the secondary rocks, and sometimes also in alluvial soil.

It has been remarked that the ores of iron are richer, of a purer quality, and more abundant in the northern than in the southern regions of the earth.

Mines of Iron.—There are few countries in the world which do not contain mines of iron, and there are few also who have made any progress in improvement and civilization, who do not extract the ores, and convert them to the various useful purposes for which that metal, above all others, is peculiarly valuable.

Britain.—The extraction and manufacturing of the ores of iron commenced at a very early period in this country, and within the last 30 or 40 years numerous extensive establishments have been made in various parts of the kingdom. The ores of iron are met with in great abundance in the county of Cumberland, where there is a band of solid ore 24 feet in thickness. This began to be wrought on a large scale about the year 1784, for the purpose of exporting it to the Carron and other iron works in Scotland. In 1791 and 1792, the amount of the annual exportation exceeded 20,000 tons. This ore was thought necessary to smelt along with the iron stones, which are the chief native materials from which the iron is extracted in Scotland; but from improvements and discoveries made in the smelting operations, they are found to succeed without the aid of this ore, so that its importation has now greatly declined. But the principal materials of the iron works in Britain are the iron stones, which are found accompanying coal strata. These are either in the form of rounded flattened nodules, imbedded in the strata of aluminous schistus, or in the form of beds of various thickness, also constituting some of the strata which accompany coal. It would exceed our limits even to enumerate the various iron works which have been established in different parts of England and Scotland. In the northern part of the kingdom, those of Wilsonton, Cleland, and Shots in Lanarkshire, and of Carron in Stirlingshire, which is on the largest scale of any in Britain, are the most important and extensive establishments.|

France—contains numerous establishments of the same kind, which have been greatly extended since the commencement of the revolution. The iron ores are chiefly met with in the vicinity of the Pyrenees, and they are deposited in veins, some of which are from six to eight feet thick. Iron stones are also abundant in France, and particularly in those parts of the kingdom where coal strata are predominant.

Island of Elba.—This island possesses one of the richest iron mines in the world, the existence of which seems to have been known from the earliest ages. The ore is chiefly specular iron ore, and constitutes an entire mountain, which is surrounded by mountains of granite, of which the island is chiefly composed. The mountain containing the mass of ore is called Rio, and is about

500 feet in height, and about 3 miles in circumference. The surface of the mountain is covered with a reddish ochry earth, which is full of small shining scales of iron ore. This earth is in some places several feet in thickness. Under this the whole mass of the mountain consists of metallic ore, or rather, it is composed of accumulated masses thrown together without any regular beds, and without any order. The masses are deposited in an ochry substance, which may be considered as their matrix; and beside the specular ore, which is predominant, the other species and varieties of iron ores are sometimes met with.

The iron mines in Elba were wrought in the time of the Romans by means of excavations carried into the mountain; but now the ore is dug out to the day in the manner of an open quarry.

Ferber has conjectured that, as the iron ores in the mines of Rio in Elba are of the same nature with those in the Tuscan territory, and as they have the same position, they are to be considered as a continuation of the same body of ore; and hence it is inferred by Patrin, that the mass of ore in the island of Elba is part of a great vein of immense extent.

Spain.—The principal iron mines in this kingdom are in the provinces of Biscay and Catalonia; and the ores from which iron is chiefly extracted are sparry ore, red and brown hæmatites.

Germany.—Many parts of Germany have been long celebrated for the great abundance and excellent quality of the iron which is extracted from the native ores, particularly in Stiria, Carinthia, and Franconia.

Sweden and Norway.—The iron mines of Sweden have been long celebrated on account of the rich ores which they afford, and the excellent quality of the iron. The most remarkable are those of Danemora, discovered in 1470, and which are situated at the distance of four Swedish miles from Upsal. These mines are in primitive rocks, and the ore, it is said, forms entire mountains; but according to the account of others, it is deposited in the form of a great vein. It is wrought to the day, and the greatest depth is 80 fathoms.

Twelve hundred persons are constantly employed in the different operations connected with these mines.

The mountain of Taberg in Smoland, which is very steep, and of considerable elevation, is remarkable on account of the great number of veins in a vertical position, and parallel to each other, of which it is composed. The ore is a mixture of specular ore, clay, and small grains of feldspar, thus exhibiting the appearance of porphyry rock.

The mines of Arendal in Norway furnish abundance of iron ore, mixed with garnets and other minerals, which are only found in primitive rocks.

Siberia.—The Uralian chain of mountains, so rich in other metallic ores, contains also valuable iron mines, from which a great part of the iron employed in Russia and in the rest of Europe is derived. In one part of Siberia, iron is extracted from an ore which consists of ferruginous fossil wood, found embedded in clay and sand.

America.—Of the ores of iron in South America, excepting what are met with in the mines of the other metals which are more sought after in that country, little is known; but in North America there are numerous iron works established on an extensive scale, from which it may be presumed that the ores of iron are abundant natural productions.

Some of the ores of iron have been met with in New Holland, or in some of the territories connected with that extensive region. I have in my possession a fine specimen of magnetic iron ore, which is said to be from Van Diemen's Land.

SECT. VII.

ORES OF LEAD.

Lead is by no means an uncommon natural production. It is met with in many places of the world, and in some in great abundance.

Ores of Lead.—Excepting in the native state, lead exists in all the different forms and combinations in which metallic ores are found in the earth.

Galena, or sulphuret of lead, is the most common ore of that metal: It presents different varieties, which are denominated by different names, as common galena, which is found massive, or crystallized in various forms, compact galena, and steel-grained galena. There is a variety called slickenside in Derbyshire, and in the county of Durham seeing-glass, or looking-glass ore, from its specular and shining appearance. The colour of these ores is lead or steel gray, and the sp. gr. is from 7·2 to 7·5. The constituent parts are sulphur and lead in various proportions. The proportion of lead is from 50 to 80 *per cent.* but the ore generally contains a little silver, and sometimes antimony.

Earthy lead ore is either in a friable or indurated form, and of a sulphur or ochre yellow colour. It is easily reduced before the blow-pipe into a black slag, and effervesces a little with acids. The constituent parts are supposed to be a mixture of oxide of lead with a little oxide of iron, and some earthy matters.

Blue lead ore is usually crystallized in regular six-sided prisms. The colour between lead gray and indigo blue; sp. gr. 5.4. The constituent parts are not precisely ascertained. It is supposed to be a green lead ore, which has undergone some change in its chemical constitution, but retains its original form.

Black lead ore is also most frequently crystallized in irregular groups; colour grayish black; sp. gr. 5·7. Constituent parts oxide of lead 78·5, carbonic acid 18, carbon 1·5, water 2.

White lead ore, or carbonate of lead, is usually crystallized in four or six sided prisms; colour yellowish or grayish white, with some degree of transparency; sp. gr. 6·4 to 7·2. Effervesces strongly with acids. Constituent parts, oxide of lead 73 to 82, carbonic acid 16 to 24, water 2 to 3. But some of the carbonates of lead have also in combination with them a small portion of iron and earthy matters.

Brown lead ore is also usually crystallized, of a reddish or clove brown colour. Sp. gr. 6 to 6·9. Constituent parts are oxide of lead 78, phosphoric acid 20, muriatic acid 2.

Green lead ore, or phosphate of lead, appears in different forms, but is often regularly crystallized. The colour is olive or emerald green, grayish, greenish, or yellowish white. Sp. gr. 6·9. Is not reduced before the blow-pipe, but melts easily into a polyhedral globule. Constituent parts, oxide of lead 77 to 80, phosphoric acid 18 to 19, muriatic acid 1·6, and sometimes a small proportion of iron.

Yellow lead ore, or molybdate of lead, is most frequently crystallized in rectangular four sided tables; colour wax or honey yellow; sp. gr. 5·4 to 5·7. Decrepitates strongly before the blow-pipe. Constituent parts, oxide of lead 58 to 63, molybdic acid 28 to 38, silica 4, and sometimes a small proportion of oxide of iron and carbonate of lime.

Red lead ore, or chromate of lead, is usually crystallized in four or six sided prisms. The colour is a beautiful aurora or hyacinth red, and the sp. gr. 5·7 to 6. It does not effervesce with acids, but decrepitates a little before the blow-pipe, and melts into a black slag. The constituent parts are oxide of lead 64, chromic acid 36.

Arseniate of lead exists sometimes in an earthy form, and sometimes in silky filaments, or crystallized in small six-sided pyramids. The colour is citron or greenish yellow; it melts easily into a globule of lead, giving out a garlic smell; sp. gr. 5·04. It is composed of oxide of lead and arsenic, with some oxide of iron and earthy matters.

Sulphate of lead is met with crystallized in irregular octahedrons; is of a snow white or yellowish white colour; sp. gr. 6·3. Insoluble in nitric acid, but may be reduced even in the flame of a candle. Constituent parts, oxide of lead 70·5, sulphuric acid 25·75, water 2·25.

Murio-carbonate of lead is found crystallized in cubes, under various modifications; colour straw yellow or pure white; sp. gr. 6·06. The constituent parts are muriate of lead 59, and carbonate of lead 40.

Repositories of Lead.—Lead, with the exception of iron, is one of the most abundant of the metallic substances found in Europe. The most common ore of lead is the sulphuret or galena; and it is met with not only in primitive but also in secondary mountains. It is generally deposited in powerful veins, or in extensive beds. The rocks in which it is most commonly distributed are gneiss, micaceous schistus, limestone, and gray wacken; and the mineral substances which constitute the matrix or gangue are quartz, barytes, lime spar and fluor spar. The ores of lead are also accompanied by a great number of other metallic substances, and particularly by some of the ores of zinc, as blende and calamine, iron and copper pyrites, sparry iron ore, and red and vitreous silver ore.

It might afford a curious subject of investigation and comparison, to consider the remarkable difference which subsists between the matrix or vein stones which accompany the ores of lead in England and Scotland. In most of the lead mines in England, the vein stones are very generally fluor spar, and in many places it is very abundant, occupying a very large proportion of the cavity of the vein; but in Scotland no trace of fluor spar has ever been discovered, excepting in one place in Aberdeenshire; and although it is probable that it is deposited in the form of a vein, no indications have yet appeared to show that it is accompanied by lead ore. It might perhaps be said, that the rocks which contain the lead mines in the two countries are very different. This is undoubtedly true to a certain extent; but some of the lead veins in Scotland are situated in rocks of the same nature with those in England where fluor spar abounds. The lead mines of the island of Islay are in limestone, as well as those in some parts of England; but fluor spar has never been known as a production of the mines of Islay.

Mines of Lead.—It has been observed that lead is one of the most abundant metallic substances which exist in Europe; so that the most valuable mines of lead are limited to that quarter of the globe.

Britain.—The lead mines of Britain are numerous and important. The mines of Derbyshire, it is supposed, were wrought in the time of the Romans, the proofs of which are derived from blocks of lead which were found with Roman inscriptions upon them. A pig of lead of this kind was discovered on Cromford moor, in the year 1777, and the interpretation of the inscription which has been given is the following: "The sixth legion inscribes this in memory of the Emperor Adrian." Another block of lead was met with in Matlock bank in 1783, the inscription on which has been translated as follows: "The property of Lucius Aruconius Verecundus, merchant of London." The weight of this block is 84 lbs. Another block, weighing more than 12 stones, was found also at Matlock at a later period, with the following inscription: "Ti. Cl. Tr. Lut. Br. Exarg." which are supposed to be the abbreviations of *Tiberii Claudiani Triumviri Lutiidari Britannorum Exargentaria.* The Saxons and Danes, it is supposed also, were engaged in working the mines of Derbyshire; the proof of which is drawn from the Odin mine at Castleton, which, it is conjectured, was so denominated from the name of one of their deities, and previous to the general introduction of Christianity into this country. From this time, through the whole period of the English history, the lead mines of Derbyshire have always been an object of attention.

The rocks in which the lead veins of Derbyshire are distributed, are chiefly limestone, some of which affords beautiful varieties of marble. Some beds of this limestone are of very great thickness. They alternate with beds of amygdaloid or toadstone, by which it was supposed that the veins, even when they were of considerable thickness, in traversing the limestone, were entirely cut off; but it appears from later and more accurate observations, that this is not the case, for the vein is actually continued through the toadstone, although it is very thin, and sometimes contains no metallic ore. From this circumstance, it is probable, arose the generally received opinion, of veins being entirely intercepted by the toadstone.

The veins of Derbyshire are of three descriptions; the first is called *a pipe work*, or pipe vein, and lies between two rocks of limestone, which regularly extend above and below. It consists of several lines or branches running nearly parallel to each other; and although they sometimes deviate from that course, they generally return after a short distance. The branches communicate with each other by means of slender threads, or *leadings*, in the language of the miners. Sometimes the surrounding rock is penetrated by these transverse threads, and by pursuing these thin veins, a new repository of metal is discovered. The two other kinds of veins in this district are rake veins, traversing the strata, and flat works, forming beds along with the horizontal strata. The flat works are generally found near the surface; but these different kinds of veins have been already sufficiently described.

The prevailing ore in the mines of Derbyshire is galena; but many of the other ores of lead, as the carbonates and the phosphates, are not uncommon. These ores are usually accompanied by barytes, lime spar, fluor spar, and manganese, with some of the ores of zinc and iron. Slickenside, which is a variety of galena or sulphuret of lead, is also a production of these mines. This galena presents a smooth surface, with a bright metallic lustre, which produces a strong reflection. This variety of lead ore forms a thin plate, adhering to a substance called *kevel* or *cawk*, which is a compound of calcareous spar, fluor, and barytes. This slickenside sometimes forms the sides of cavities, in the opening of which by the workmen some inexplicable phenomena are produced; for when such a cavity is pierced with the miner's instrument, it cracks and splits, and at last explodes with great violence. Before the miners were aware of the danger to which they were thus exposed, accidents took place; but knowing the effects, when they suspect their operations to be near a cavity of this substance, they merely scratch it with the point of the pick, and then retreat to a place of safety; in a short time the explosion is produced, by the force of which considerable masses of the ore, and the other materials of the vein, are detached.

Fluor spar is one of the common vein stones of lead ore in this district; but there are some places in which the veins are entirely filled with that beautiful mineral, which in that country is called *Blue John*, and elsewhere is better known by the name of Derbyshire spar. In one of the mountains near the Peak of Derbyshire, there are two mines which furnish the materials for the extensive manufactory of ornamental articles into which the fluor spar is formed. The pieces of fluor, as they are found in the veins or cavities, are generally about three or four inches thick, sometimes they reach a foot in thickness, and they are usually found in detached masses, in cavities filled with clay, and other loose matters.

Elastic bitumen, or mineral caoutchouc, an inflammable substance, is also a production of these mines; and I believe is peculiar to Derbyshire. It is found between the stratum of schistus and the limestone, and sometimes also in small cavities, adhering to the matrix, or containing lead ore, fluor, &c.

The annual produce of the lead mines in Derbyshire, according to the statement of Pilkington, may be computed on an average at between 5000 and 6000 tons: this was previous to the year 1782. A single mine, the Gregory mine at Ashover, from the year 1758 to 1783, yielded lead to the value of L.105,986. The annual produce of lead during this period was 1511 tons on an average *.

Some of the northern counties of England contain very valuable lead mines, as those of Weardale, at the head of the county of Durham, where the veins are distributed in a gray wacken, called by the miners of the district *hazle whin*, and limestone; those of Allenheads, on the other side of the same ridge, and those of Alston moor, lying

* Pilkington's Derbyshire, vol. i. p. 95, 128.

to the south-west, in the county of Cumberland. In these districts many excellent veins of lead ore have been wrought, and they are frequently accompanied with great bodies of fluor spar.

Some of the lead mines of Scotland, and in particular those of Leadhills and Wanlockhead, discovered in 1540, have been long celebrated on account of their mineral riches. The prevailing rock in which the veins at Leadhills are distributed, is gray wacken, and the general course of the veins is from north to south, with an inclination to the east. The thickness of the veins varies much; but some of the principal ones are from four to ten feet thick, and at one time the Susannah vein, one of the richest and most productive yet discovered in that district, or perhaps in Scotland, exhibited a mass of ore no less than 14 feet thick. It is true, indeed, that the extraordinary thickness of the vein at this place, arose from the junction of some strings or branches of small veins.

The principal lead ore of Leadhills and Wanlockhead, which may be considered as the same district, although they present a considerable diversity of mineral productions, is galena, of which there are several varieties. Carbonate of lead, in acicular crystals, was at one time found in great abundance in the Susannah vein, but it is now rarely met with. At Wanlockhead, the tabular variety of that lead ore was formerly most common. Green lead ore, or the phosphate of lead, is usually found at the top of the veins, and some suppose that the galena has undergone some change, by which it appears under this new combination; but these facts have been already noticed in the general remarks on metallic veins.

The matrix of the ores at Leadhills is usually limespar, heavy spar, quartz, manganese, and clay; and the accompanying metallic ores are blende, calamine, iron ores, and some copper ores.

The produce of the mines of Wanlockhead and Leadhills is sometimes very considerable. A few years ago the annual amount of lead produced at Wanlockhead was 1000 tons, and that at Leadhills was 1400 tons. The lead then sold for L. 20 *per* ton, thus yielding a return of L. 48,000 *per annum* *.

The whole of that country, to a very considerable extent round Leadhills, may be regarded as a mining field. At Gilkerscleugh, the property of Daniel Hamilton, Esq. which is five miles to the north of Leadhills, the places where operations were formerly carried on, in searching for lead ore, are still visible; and among the rubbish which was thrown out during these operations, I observed the various mineral substances which usually accompany metallic ores, such as quartz, heavy spar, and limespar, with some fragments of the

* See Map of Dumfries-shire.

metallic ores themselves. But two years ago, in consequence of some researches which were made under the inspection of the proprietor, I had an opportunity of examining a regular vein, which presented a very favourable indication of bearing ore. It was in the bottom of a shaft about two fathoms depth, which was sunk on the top of the vein, where the ores which appeared were, as is usually the case, green lead ore, with some specks of galena; but in sinking a little deeper, pure galena was found, from which lead of an excellent quality was extracted. As no machinery was erected to carry off the water, which began to increase in sinking deeper, the researches were interrupted; but so far as they were prosecuted, I have no hesitation in saying that the appearances are extremely favourable.

There were formerly lead mines at a place called Black Craig, in Galloway, and Tyndrum, in Argyleshire; but as they ceased to be a profitable concern, I believe the operations have been for some time interrupted at both places. The only other lead mines in Scotland at present in a state of activity, are those of Strontian on the west coast of Argyleshire, and of the island of Islay.

The lead veins at Strontian traverse gneiss rock, and are remarkable for having produced the mineral which derives its name from the name of the place. That mineral, or carbonate of strontites, like many other mineral productions, appears to have been limited to a particular spot, for it was formerly found in great abundance; but as the operations have been extended, it is now more rarely met with.

The lead mines of Islay, which it is supposed were wrought so early as the time of the Danes, are in veins which run in primitive limestone. Some of these veins were formerly wrought to the day, and one of them is remarkable by being included between the limestone and an immense whin dyke.

France.—This country possesses considerable lead mines, particularly those of Poullaouen and Huelgoat, in the department of Finisterre. These mines are in two powerful parallel veins included in primitive rocks. There are also mines of lead in the Vosges, where the galena is disseminated in a thick vein of granite, which seems to be decomposed. The ore is mixed with a good deal of red iron ore. The lead mines in the department of Sambre and Meuse, are in veins which traverse limestone nearly in a vertical position. Beside these there are some other lead mines, which are similar in their distribution and productions to the lead mines of Britain already described. The produce of the mines of France is stated at 30,000 quintals of lead annually.

Germany.—There are many valuable mines of lead in this country, particularly in Saxony and the Hartz. Lead ore is also an abundant production of the mines of Bohemia and Hungary, yielding sometimes a considerable proportion of silver.

The galena, which is the prevailing ore of lead found at Bleyberg in Carinthia, is deposited in beds, of which there are 14, alternating with those of a compact limestone, and the celebrated fire marble; or in grains disseminated in a rock composed of a tender siliceous sandstone and rounded pebbles. The latter is accompanied with oxide of copper and brown iron ore. The mines of Bleyberg furnish the finest specimens of molybdate of lead.

At Tarnowitz in Silesia there is a remarkable deposition of lead ore. The beds, in which the ore is distributed, repose on horizontal strata of compact limestone, containing imbedded petrified shells, and impregnated with bituminous matter. The bed, of which the ore forms part, is a limestone penetrated with iron ochre, and including some grains of galena; and it is principally composed of a brown ferruginous marl. In this bed the lead ore is deposited in veins, in rounded masses, or in small grains. The bed lies in a waved position, and it is observed that the concave parts are richer in ore than the convex parts of the bed. It is covered with a compact limestone, containing ores of iron and zinc, a bed of ferruginous marl, and a bluish spongy clay.

Siberia.—This region of the globe, so rich in other mineral productions, does not contain a single mine of lead in any part of the two immense chains of the Uralian or Altaian mountains.

The lead which is employed in the cupellation or refining of the precious metals, is carried from the rich mines of Daouria, at the distance of 700 leagues.

The only appearance of lead in the immense chains of mountains now mentioned, is the red lead, or chromate of lead, which was first discovered in Siberia, and of which the gold mine of Beresof is still the principal repository. It is found in a small vein of ferruginous quartz, which traverses a gneiss rock, which is of a reddish colour, and resembles a sandstone.

SECT. VIII.

ORES OF TIN.

TIN in the metallic state is of a silvery white colour; it possesses more hardness, and more ductility and tenacity than lead. Sp. gr. 7·2. It is one of the lightest of the ductile metals.

Ores of Tin.—The ores of tin are not numerous. It is chiefly found in the state of oxide, or combined with some other metallic ores.

Tin pyrites is found massive or disseminated, is of a steel gray colour, or sometimes bronze yellow; sp. gr. 4·3 to 4·7; melts easily before the blow-pipe into a black slag, giving out a sulphureous smell, but is not reduced. The constituent parts are tin 34, copper 36, iron 3, sulphur 25, with some earthy matters.

Common tin stone, or oxide of tin, is found massive, disseminated, in rounded grains, and often crystallized in rectangular four-sided prisms. Colour brownish black, yellowish gray, or grayish white; sp. gr. 6·3 to 6·9; decrepitates before the blow-pipe, and is partially reduced to the metallic state. Constituent parts are tin 77·5, oxygen 21·5, with a small portion of iron and silica. From its peculiar lustre it is sometimes called *resin tin*. This ore is sometimes collected in alluvial soil, where it is in the form of grains or sand, and then it is known by the name of *stream tin*.

Grained tin ore, or wood tin, is found in small rounded or angular pieces; it has a fibrous fracture, and the fragments are wedge-shaped; the colour is various shades of hair brown; sp. gr. 5·8 to 6·7. Before the blow-pipe it becomes brownish red, and then decrepitates strongly, but is infusible. The constituent parts are tin 91, and oxide of iron 9. In some specimens arsenic has been detected.

Repositories of Tin Ores.—The ores of tin are limited to a very few regions of the globe; but in the places where it is deposited, it is sometimes met with in considerable quantity. The general repository of tin is granite, or some rock which is allied to granite, and in contact with it; and the granite containing tin is usually in a state of decomposition.

The ores of tin are generally distributed in veins, and at no great distance from the surface. Tin veins have this peculiarity, that they are frequently not accompanied with vein stones, like other metallic ores; the tin ore occupies the whole space of the vein, and is closely attached to the granite rock.

The granite rock itself often contains the tin ore disseminated through its whole substance. Grains of tin ore, as already noticed, are also collected in alluvial soil. This ore, called *stream tin*, probably derives its origin from the decomposition of the granite, to which it has a remarkable tendency. Tin also exists in some of its repositories in accumulated masses or stockwerks.

Mines of Tin.—From the limited distribution of tin ores, the mines of that metal to be enumerated are very few; and they are confined to England, Germany, Bohemia, and the East Indies.

Britain.—The only tin mines in Britain are those of Cornwall, which have been known from the earliest ages, and continue to be the most productive of any yet discovered. It appears from ancient historical records, that the Phenicians traded to Britain for the sake of the tin; and from this it is inferred that the discovery of tin in Cornwall must have been made at least 2400 years ago; but it is supposed that the only ore then wrought was stream tin, which is most accessible, and at that period probably existed in great abundance. For it seems to be pretty certain, that mining, or digging the ore from veins, was unknown till about the year 1000 of the Christian æra *.

The tin ores of Cornwall are found in all the different states enumerated above, as the repositories of that metal. The general direction of the tin veins of Cornwall is from east to west, or a few points deviation from that course; and if they are not interrupted or deranged by other vertical strata, they preserve the same course in traversing a considerable extent of country. These veins sink into the earth with various degrees of inclination. Sometimes they become so oblique as to approach nearly to the horizontal position, and in this case they come under the denomination of *flat works*. Some of these veins continue flat or horizontal for a short distance, and yield ore; then they go down perpendicularly with only a small string, by which their course may be traced,

* Pryce, Mineralog. Cornub. Introd.

resume their horizontal position, and again dip downwards in a vertical direction, somewhat in the manner of steps of stairs. The tin veins are included in granite, or, as it is called in Cornwall, *moor stone*, which is usually in a loose state of aggregation, or tending to decomposition.

In some places tin and copper veins are united, and run parallel to each other, the tin ore forming one side, and the copper ore forming the other side of the vein. But it rarely happens that the vein continues rich in both ores at the same time; for when the tin ore is abundant, the copper ore is in small quantity; and when the produce of the latter from the same vein increases, that of the former is diminished. The ores of tin are generally near the surface, while those of copper usually lie at a greater depth.

As a proof of the ores of tin being deposited near the surface, it is mentioned, that in working a vein some distance under the sea, the miners approached so near to its bottom, as to leave a space of four feet thick only between the bottom of the ocean and the spot in which the operations were carried on. The sound of the agitated waters was distinctly heard, and during a storm, it became so tremendous, that the miners were terrified, and abandoned their work.

The ores of tin have been sometimes, but rarely, found in accumulated masses or stockwerks in Cornwall. These are called in the country *pipes* or *bunnys* of ore, and they are examples of the pipe veins of the author of the preceding work.

The third repository of the tin ores of Cornwall is in the alluvial soil, which is deposited in the valleys. The stream tin is collected in such places. In St Austle moor there is a depth of 18 feet of alluvial soil. The first stratum, reposing on the solid rock, which it has been observed is entirely destitute of tin ore, consists of stream tin of various thickness. A layer of earth, clay, gravel, &c. comes next, and then another stratum of tin ore, and so on successively to the surface. In St Blazey moor, there is a depth of 20 feet of alluvial soil. The first stratum next the surface is composed of gravel, the next is mud, the succeeding stratum is gravel containing a little tin ore, and this last reposes on a bed of black mud, which is probably turf or peat, for it is described as fit for fuel. Immediately under this lies a bed of stream tin about five feet thick. Great part of this stratum had been wrought out at a very remote period, and before iron instruments were in use; for several wooden pick-axes, made of oak, holm, and box, were discovered in it a few years ago.

The singular occurrence of a mass of pebbles of chlorite schistus, cemented by crystallized tin, in one of the mines of Cornwall, is too remarkable to pass unnoticed. It was observed in the Relistian mine, which is nearly on a level with the surrounding country. The vein has been wrought to the depth of 12, 25, 50, and even 90 fathoms from the surface. It varies in width in different parts; the greatest width is 36 feet, and in this part the principal operations are carried on. Its course, as usual, is east and west; but at the distance of 100 fathoms east it diminishes to five feet wide. Excepting the metallic substances, the vein consists of schistus, chlorite, and quartz, which latter forms the smallest component part. In sinking a shaft, at the distance of eight fathoms north of the widest part of the vein, a flookan or cross dyke about two inches thick, the course of which is south-east, was discovered. It cuts the vein at an angle of 45°, and produces a derangement.

At the depth of 12, 25, and 50 fathoms, nothing appeared in the vein but the old workings; but at the depth of 65 fathoms close to the cross dyke, a great number of angular pieces of schistus, cemented by the same substance, was found. At the depth of 75 fathoms, the cross dyke increased to four inches thick, and continued of that thickness for ten fathoms; after which it divided into four branches, each diverging from its former course, and in this state it continued through the vein, of which the first three feet were composed of copper pyrites, and then there appeared a body of pebbles nearly 12 feet square, and extending in width to the extreme branches of the cross dyke. The schistus predominates in this part of the vein; the pebbles of course are generally composed of schistus, cemented in some parts by the chlorite, in others by tin ore, which is generally crystallized. Some copper pyrites was detected in the crevices. It is stated as a singular circumstance, that a few pebbles, not exceeding 10 or 12, composed of tin and quartz, coated with chlorite, were found. The body of the mass of pebbles did not exceed two fathoms in height, but single pebbles were found four fathoms above, and six below the mass; but at the depth of 15 fathoms below it, none were met with, and the strata were undisturbed *.

The annual produce of the tin mines of Cornwall has been stated at 3000 tons of tin; and according to the estimation, that quantity of metal is extracted from 126,000 tons of tin stuff, as it is called, or tin ore †.

Spain.—That part of France which lies between Cornwall and the province of Galicia in Spain, is supposed, merely from some similarity in the nature of the rocks, to afford indications of tin. None, however, has yet been discovered; but in the province of Galicia in Spain, and on the frontiers of Portugal, a mine of tin was begun about the year 1787 in veins, some of which were a fathom in thickness, and included in granite. The tin ore was in grains, and sometimes in

* Phil. Trans. 1807, p. 298.
† Pryce, p. 186.

masses of considerable size. Tin mines were formerly wrought in the north of Portugal, and some traces of the ore are still visible; but it does not appear that any of these mines have risen to much importance.

Germany.—The tin mine of Marienberg is in a vein which runs from east to west, like those of Cornwall, with an inclination of about 70°. The thickness of the vein is about a fathom, and in the middle it contains about seven or eight inches of yellow copper ore, mixed with tin ore. The rock which accompanies the vein is a gray schistus, with black and white mica resembling gneiss. The rock itself contains tin ore, and it is sometimes sufficiently rich to be dug out for the extraction of the metal.

The mountain in which are situated the tin mines of Ehrenfredericksdorff, contains within a space of about 100 fathoms a great number of parallel veins, running in the same direction, and some of them almost in contact with each other; so that in the thickness of three fathoms there are sometimes four or five veins, the hanging side of one vein forming the ledger side of the other. These veins traverse a rock of argillaceous schistus. Some of the veins have been wrought to the depth of 14 fathoms, and others to that of 40.

The tin mines of Gayer in Saxony were wrought in the 12th century; and, according to Pryce, the method of searching for tin, and also of working it, were introduced by a Cornwall miner into this country. The mines are on the summit of a mountain, in which the ore is accumulated in a great mass. The operations still continue to be carried on in the place where they first commenced. In former times the mine was wrought to the day in the manner of an open quarry, to the depth of 20 or 30 fathoms, in a space of 100 fathoms diameter. This space contains a reddish sandstone, according to the description given of it; but this sandstone is supposed to be granite in a state of decomposition. In this stone the ore is disseminated in small grains, and the rock is traversed by a great number of small veins, crossing each other in all directions. It may be added, that the rock called sandstone is undoubtedly a granite, from the circumstance of being surrounded by gneiss, or micaceous schistus, in which it is observed that the produce of ore is considerably less than in the granite.

Bohemia.—The tin mines of Platte are as usual in granite, which is of a reddish gray, or greenish colour, and the veins traverse the rock in a direction approaching to east and west. Thin separate veins have been discovered, divided from each other by thin layers of decomposed granite. Distributed in this manner, the veins extend to the depth of 40 fathoms, where, meeting with a bed of clay, many of them unite, and then form only three or four, which occupy a space of from two to five fathoms in thickness. At this depth they continue rich in tin stone. The greatest depth to which these mines have been wrought, is 80 fathoms*. In the Kaff mountain, a tin mine has been wrought, in which iron ore is found at the top of the vein, and tin at a greater depth; and it has been conjectured that, in going deeper, it might produce silver ores. The tin veins are described as being nearly in a horizontal position, probably like those of Cornwall, and from this circumstance they have been considered by the miners as flats, or horizontal beds. It has been observed in these tin veins, that when they are traversed by vertical veins, they become deaf, or no longer produce tin ore. The produce of tin is also diminished when they are united with silver veins.

But the most remarkable tin mine of Bohemia is that of Schlackenwald, the ore of which is deposited in the form of accumulated masses or stockwerks. One of these masses is of very considerable magnitude. It is in the form of an inverted cone, the upper part of which is 100 fathoms; and at the depth to which the operations have been carried, it is diminished to 92 fathoms in diameter. It is surrounded by a gneiss rock, and the mass itself is composed of granite, in

* Born's Travels, p. 260.

which are disseminated grains of tin ore. This mass is also traversed by veins of quartz, in various directions, which are very rich in tin stone; and they are accompanied with fluor spar, wolfram, and copper pyrites. The whole stock, it has been observed, contains grains of tin ore, but it is more abundant in the parallel stripes or veins which cross a gray or reddish granite.

This mine has been wrought for more than 530 years, and the operations have been carried to the depth of 100 fathoms; the ore is so disseminated in the rock, that it requires 10,000 quintals to yield 35 or 40 quintals of tin *.

East Indies.—There are some mines of tin in Malàcca and the island of Banca, in the East Indies. The latter, it is said, has yielded to the Dutch not fewer than 3,000,000 lbs. of tin, and still the vein seems far from being exhausted; but of the nature of its repository, no precise information has been obtained. The tin of the East Indies is said to be purer than that of Europe.

* Born's Travels, p. 268.

SECT. IX.

ORES OF ZINC.

Zinc in the metallic state is of a brilliant white colour, with a bluish shade, and of a distinct lamellated texture. The sp. gr. is 7·19. Zinc was formerly considered as one of the brittle metals, and arranged, according to the older chemical distinctions, among the semi-metals. It had indeed been observed, that it might be formed, by gradual and cautious pressure, into thin plates, which possessed some degree of elasticity. But by a late discovery, the method of manufacturing zinc was secured by patent to Messrs Hobson and Sylvester of Sheffield. Their process is very simple. The zinc is heated to a temperature of between 210° and 300° of Fahrenheit, and in this state it is rolled or hammered, or may be drawn into wire. When it cools, and is brought again to the temperature of the atmosphere, it does not return to its former brittleness, but continues soft, flexible, and ductile. It ought to be mentioned, however, that a prior claim to this discovery has been made in favour of Mr Sheffield of Somerstown, who, it is said, 20 years before, had concluded that zinc at a certain temperature was not less malleable than other metals, and that it might be drawn into wire, or laminated between rollers *.

When zinc is heated to redness in an open vessel, it suddenly takes fire by agitating the vessel, and burns with a brilliant white and greenish flame. The zinc is thus oxidated, and rising in the form of vapour, is condensed in the air in filamentous white flakes, which are called flowers of zinc, *lana philosophica*, or philosophic wool.

Ores of Zinc.—Zinc has never been met with in the metallic state. It exists in the form of sulphuret, in that of oxide, and also in the state of carbonate.

Blende, or sulphuret of zinc, assumes various appearances, and is either massive or disseminated, or crystallized in the form of cubes, or octahedrons. It is of a dark sulphur yellow, olive green, or brownish red colour. Sp. gr. 4 to 4·16. Before the blow-pipe it decrepitates, and becomes of a gray colour, but is infusible. Two varieties have been described; the yellow blende, which becomes phosphorescent by friction in the dark, and is composed of zinc 64, sulphur 20, iron 5, fluoric acid 4, water 6, silica 1; and brown blende, which is the most common variety, and

* Phil. Mag. vol. xxiii. p. 282.

whose constituent parts are, zinc 44, sulphur 17, iron 5, silica 24, alumina 5, water 5.

There is still another variety called *black blende*, which is also crystallized like the former, and is distinguished by many of the same characters, but is of a perfect black, brownish black, or blood red colour, and often iridescent. It is composed of zinc 45, sulphur 29, iron 9, lead 6, silica 4, water 6, and arsenic 1.

Calamine, or oxide of zinc, also presents several varieties, as compact calamine, which is found massive or disseminated, cellular, or stalactitical, has an earthy fracture, and a grayish white, yellowish, reddish, or milky white colour. Sp. gr. 3·5 to 4·1. When suddenly heated, decrepitates before the blow-pipe, but is infusible; forms a jelly with acids. The constituent parts are, oxide of zinc 84, silica 12, iron 3, alumina 1, and sometimes a portion of water.

Some varieties of calamine effervesce strongly with acids, and are composed of oxide of zinc 65, carbonic acid 35. Some have also been examined, in which 15 parts of water were detected. These varieties, therefore, must be considered as carbonates of zinc.

A native sulphate of zinc, it is said, has also been found in the form of white shining filaments, or in that of stalactites, also of a whitish colour. This, however, appears to be a rare natural production.

Repositories, &c. of zinc.—As the ores of zinc generally accompany the ores of other metals, they are scarcely to be considered as having any appropriate repository. The ores of zinc, especially blende, or the sulphuret, are far more common in mines of lead, than in those of any other metal. They are met with in greater or smaller proportion in almost all lead mines; and from this circumstance, before the nature of the ore was distinctly ascertained, they were frequently taken for a variety of galena; but affording no lead by the usual process of smelting, they were denominated *blende*, or blind lead ore, and sometimes *pseudo galena*. It may, however, be observed in general, that the sulphuret of zinc exists, not only in the primitive, but also in the secondary class of rocks, while the oxide and carbonate of zinc are more commonly, though not exclusively, confined to the latter.

Britain.—The ores of zinc are very common in some of the lead mines of Britain. Derbyshire affords a great quantity of the ores of that metal, and particularly in the form of calamine. That ore is found at various depths, and generally near a vein of lead ore: sometimes the two substances are mixed together, or run a considerable way parallel to each other; but it happens more frequently that the one is cut off when the other begins to make its appearance, according to a common observation of the miners, that a good vein of both is never met with in the same place.

The principal places of Derbyshire where calamine is abundant, are Castleton, Cromford, Bonsal, and Wirksworth. The ore is generally deposited in a bed of yellow or reddish brown clay, and these beds are described as in the form of pipe veins. They consist of distinct masses of various forms and sizes. The ore is accompanied with cawk, which is a mixture of barytes and lime, and also with lime spar and some lead ore.

The quantity of calamine annually raised, according to Dr Watson *, in Derbyshire, amounts to about 1500 tons, although 60 years ago the quantity was under 40 tons; but, according to Mr Pilkington, it does not exceed 500 tons. The native or crude calamine is sold for 35 or 40 s. per ton; but when reduced and prepared for use, it is valued at 5 or 6 guineas †.

In some other places, particularly at Mendip in Somersetshire, both blende and calamine are wrought very extensively, for the purpose of being alloyed with copper to form brass. Blende, and also some varieties of calamine, are frequently met with in the mines at Leadhills; the blende is occasionally in great abundance. Sometimes it

* Chem. Ess. vol. iv.

† Pilkington's Derbyshire, vol. i. p. 138.

exists in detached masses, and sometimes it occupies the whole of the vein, to the exclusion of the lead ore.

France.—In France, in a lead mine about six leagues from Cherbourg, there is a vein of calamine four fathoms in thickness; but one of the most remarkable is in the neighbourhood of Aix-la-Chapelle, where there is a prodigious mass of calamine imbedded between two rocks; the one to the south, composed of micaceous schistus and of sandstone, containing a good deal of mica, and very hard quartz; and the other to the north, which is nearly of the same nature. To the west of the mine, beds of a bluish limestone, very much inclined to the south, stretch to the north of the mass of calamine. The utmost depth is yet undiscovered, but the operations have been carried 250 feet deep. It was at first wrought by the Spaniards in the manner of an open quarry, and at least 100 feet of the ore, in all directions, was dug out. The ore is now extracted by sinking shafts, from the bottom of which galleries are driven, some of which have been carried to the distance of 150 feet. When the ore is exhausted upon this level, the shafts are sunk deeper, and a new series of operations commences, some of the shafts being carried to the perpendicular depth of 150 feet. The annual produce, from the year 1730, is stated at 1,500,000 lbs. of calamine, which is disposed of to the manufacturers of Namur, Stollberg, Germany, and some of it is carried to Bohemia and Russia *.

An immense mass of blende, or sulphuret of zinc, was discovered by Dietrich in the Pyrenees. It appeared to the day in an extent of 10 fathoms broad, and 20 fathoms high. An attempt was made to work it, supposing it an ore of iron; but when it was smelted, it excited no small degree of astonishment when the whole of the metal was dissipated. The ores of zinc are also not uncommon in other places of France.

Spain.—A very pure calamine, which contains neither iron, lead, nor sulphur, is found in the neighbourhood of Alcaras, in La Manca in Spain, and it is extracted for the purpose of being employed in the manufacture of brass in the vicinity of that place.

Germany.—Some of the ores of zinc are very abundant in the mines of Saxony and of the Hartz, and some of them exist in considerable masses and in peculiar repositories. A mass of blende, somewhat similar to that observed in the Pyrenees, was discovered in the Hartz, unmixed with any other matter, and would afford, it is said, any quantity of ore.

* Jour. des Mines, No. 13. p. 43.

SECT. X.

ORES OF ANTIMONY.

Antimony in the metallic state is of a brilliant white colour, resembling that of silver or of tin. It has a lamellated texture, being composed of plates which cross each other in all directions. It presents some traces of crystallization. Sp. gr. 6·7. It is very brittle, and may be reduced to a grayish white powder.

Ores of Antimony.—Antimony exists in nature in three different states; in the state of native antimony, in that of sulphuret, and in that of oxide.

Native antimony, which is a rare natural production, is found massive or disseminated, of a tin white colour, and before the blow-pipe is easily fused into a metallic globule, which gives out at the same time fumes having the odour of garlic. Sometimes it contains a small portion of arsenic.

Gray ore, or sulphuret of antimony, appears under various forms, as compact, foliated, radiated, and plumose. The compact gray ore is massive or disseminated, and is of a lead or steel gray colour. Sp. gr. 4·36. The foliated is distinguished by its fracture, and the radiated, which is the most common ore, is massive or disseminated, and often crystallized in acicular or capillary crystals. Sp. gr. 4·1 to 4·5; and it is composed of antimony 74, sulphur 26. The plumose variety is usually in capillary crystals, forming a superficial covering to other minerals, and is friable and brittle. The constituent parts of this variety are sulphuret of antimony, combined with arsenic, iron, and sometimes a little silver. Gray antimony, or the sulphuret, gives out before the blow-pipe white fumes having a sulphureous smell. The whole is almost entirely volatilized, or changed into a black slag.

Black ore of antimony is crystallized in rectangular four-sided tables, the crystals smooth, of an iron black colour and shining lustre. This is also a sulphuret of antimony combined with some other matters.

Red ore of antimony, or hydro-sulphuret, is massive or disseminated, but more commonly in the form of capillary crystals, of a shining vitreous lustre, and of a cherry red or brownish colour. Sp. gr. 3·7 to 4. Melts easily before the blow-pipe, and is composed of oxide of antimony 78, sulphur 20.

White ore, or oxide of antimony, is usually in superficial divergent fibres, or crystallized in aggregated rectangular four-sided tables or cubes; colour snow, yellowish, or grayish white. The crystals before the blow-pipe decrepitate, but in the state of powder are easily fused. This ore was formerly supposed to be a muriate of antimony; but its constituents appear to be, oxide of antimony 86, oxide of lead 3, and silica 8.

Ochre of antimony is found massive, disseminated, or in superficial crusts on gray antimony, has a dull earthy fracture, and is of a straw, yellow, or yellowish gray colour. It is soft and friable, infusible before the blow-pipe, but becomes white, and emits white fumes. The constituents of this ore have not been ascertained, but it is probably an oxide.

Repositories of the Ores of Antimony.—The sulphuret of antimony is the only species of the ores of that metal which is found in considerable quantity, or in veins of any extent. The other species and varieties of antimonial ores are sparingly distributed, and usually accompany the sulphuret. Veins of antimony exist both in primitive and secondary rocks. The gangue, or matrix, is similar to that which accompanies lead ores, as quartz, lime spar, and heavy spar. The ores of antimony are often found to contain a small portion of gold, such as those which are met with in Spain, Transylvania, and Siberia. Native antimony in its purest state, as well as when it contains a portion of arsenic, is met with in the fissures of a micaceous schistus.

Mines of Antimony.—Antimony, except when in combination with some other metal, as lead, is not to be considered as very generally distributed. The proper mines of that metal, indeed, are limited to a very few spots.

Britain.—Antimony is found only in a very few places in this country. It has been met with in Somersetshire, in Devonshire, and Cornwall. In the two former counties, only a small quantity, but in the latter, masses of from 20 to 30 tons have been obtained. In the years 1774, 1775, and 1776, about 100 tons were dug out from a mine called Huelboys, which sold at the rate of L. 13 to L. 14, 14s. *per* ton. The course of the antimonial veins in Cornwall is chiefly from north to south. Small quantities in other veins have been found running in a different course. The antimony is distributed very unequally in the veins, and this unequal distribution is more remarkable in the longitudinal, than in the perpendicular direction of the vein; for it is not unusual to see the vein at one place two or three feet wide, and in another, at the distance of a few feet, the ore entirely disappear, and the vein itself scarcely perceptible. The greatest depth from which antimony had been dug in Cornwall, previous to 1778, did not exceed 14 fathoms *.

* Pryce, Mineralog. Cornub. p. 48.

Scotland contains the only mine of antimony in Britain which is of any importance, or seems to promise any advantage to adventurers in carrying on the operations. This mine is at Glendinning, about ten miles from Langholm in Dumfries-shire, and is the property of Sir John Lowther Johnston, Bart. It was discovered in 1760 in searching for lead ore, but it was not regularly worked till the year 1793.

The rocks, in which the veins are included, are chiefly gray wacken. The principal ore of antimony is the sulphuret, and the matrix is usually quartz, or lime spar. The accompanying minerals are blende, sometimes a little galena and iron pyrites.

Two veins of antimony have been discovered in this field; and in one of them, which I had an opportunity of examining, the ore was from eight inches to a foot and a half in thickness. At the time alluded to, which was immediately before the operations of the last company ceased, the appearances of the ore were extremely favourable, and it seemed to be wrought with no difficulty whatever. Even that part of the mines which is below level, was then cleared of water by a hand pump.

In a short view of the mineralogy of Dumfries-shire, drawn up by General Dirom, and annexed to the county map, it is stated that the antimony mine of Glendinning, during a period of five years previous to 1798, when it was relinquished, yielded 100 tons of pure metal. This was sold at L. 84 *per* ton, making the amount L. 8400. The price of antimony at the present time is at least three times what it was ten years ago, so that these mines, if judiciously conducted, would probably be a successful speculation to adventurers.

France, &c.—Antimony is said to be common in France, as in the department of Gard, and in the department of Puy de Dome, where large specimens of radiated sulphuret of antimony in fascicular masses, in a matrix of heavy spar, are met with; in Vivarais, where a vein of antimony has been discovered in coal; and in the department of Upper Vienne. Antimony has been found in different provinces of Spain; but the only places from which it is extracted, are the mountains of La Manca, and near Santa Cruz. Antimony is also found in Hungary, in the mines of Schemnitz and Cremnitz, where it is attached to heavy spar; it is also met with in Bohemia, Saxony, Tuscany, at Saalberg in Sweden, and in Daouria in the vicinity of the river Amour in Siberia, where the antimony is deposited in a matrix of quartz.

SECT. XI.

ORES OF BISMUTH.

Bismuth is of a whitish colour, inclining to yellow, and exhibits a texture composed of large brilliant plates. By a violent stroke of the hammer, it is divided into small fragments of a lamellated structure. The sp. gr. is 9·82.

Ores of Bismuth.—Bismuth exists in nature in three different states; native, in the state of sulphuret, and in that of oxide.

Native bismuth is usually found disseminated in a plumose or reticulated form; sometimes, but rarely, it is crystallized in small four-sided tables or cubes. The colour is silvery white, inclining to red, but it is commonly tarnished. It is soft, and almost ductile; it is fusible almost in the flame of a candle, and by increasing the heat is volatilized. It is soluble with effervescence in nitric acid, and is precipitated by water in the state of white powder.

Native bismuth is rarely in a state of perfect purity. It is usually combined with a small portion of cobalt and arsenic.

Vitreous bismuth ore, or sulphuret of bismuth, is found usually massive or disseminated, and is rarely crystallized in small capillary prisms; colour between lead gray and tin white; sp. gr. 6·1 to 6·4; is easily fusible before the blow-pipe, and gives out a sulphureous odour. The constituent parts are, bismuth about 60 *per cent.* with sulphur and a little iron.

Ochre, or oxide of bismuth, is usually disseminated on the surface of other minerals, is of a yellowish gray, ash gray, or straw yellow colour; sp. gr. 4·3; is easily reduced before the blow-pipe. Constituent parts are, oxide of bismuth 86, oxide of iron 5, carbonic acid 4, water 3.

Repositories, &c. of Bismuth.—Bismuth is not very generally diffused in nature, and the places where it is deposited in considerable quantity are few in number. It is scarcely ever found in veins, or considerable masses of any kind, but is one of those metals which may be considered as concomitant with other metallic ores. Bismuth is therefore to be expected accompanying the ores of cobalt, arsenic, silver, and sometimes those of zinc and lead.

The ores of bismuth seem to be exclusively connected with primitive rocks, and the vein stones are quartz, lime spar, and heavy spar.

Cornwall is the only place in Britain where any of the ores of bismuth have been found; and there it exists only in small quantity along with cobalt *.

Bismuth is sparingly distributed in some of the mines of France, as those of Brittany; and in some parts of the Pyrenees, the sulphuret of bismuth is met with in the state of small grains, and somewhat resembling galena. From this it may be distinguished by its inferior specific gravity. In the latter place it is deposited in a vein of lime spar, which traverses gray limestone. The same vein contains galena and blende.

At Freyberg and Schneeberg in Saxony, native bismuth, as well as the sulphuret, is found in a matrix of quartz. At Schneeberg native bismuth exists in a dendritical form, not only adhering to a reddish coloured jasper, but ramified through the mass. In this state it assumes a fine polish, and is greatly valued; and sometimes, at the same place, it is in the form of large plates, which exhibit iridescent colours.

Translyvania and Bohemia also afford some of the ores of bismuth, which are imbedded in a matrix of quartz; and in Hessia the sulphuret is found on an iron ore, in fine acicular crystals of beautiful colours.

Native bismuth, and also the oxide, the latter in a hard and compact earthy mass, are met with

* Pryce, Mineralog. Cornub. p. 45.

at Los in Sweden. Patrin discovered, in the gold mine of Beresof in Siberia, some specimens of the sulphuret of bismuth, containing a portion of native gold, and attached to a greasy, changing-coloured quartz.

SECT. XII.

ORES OF COBALT.

Cobalt, in the metallic state, is of a gray colour inclining to red, and of a fine granulated texture. It is very brittle, so that it can be easily reduced to powder, which is also of a gray colour, but has little brilliancy. The sp. gr. is 7·7 to 8·5.

Ores of Cobalt.—Cobalt is never found native in a state of purity. It is either alloyed with other metals, and particularly arsenic and iron; in the state of oxide, or in that of salt.

White cobalt ore is massive or disseminated, and sometimes, but rarely, crystallized in the form of cubes or octahedrons; is of a tin white colour, but tarnished or changeable on the surface; is easily fusible before the blow-pipe, and gives out a dense vapour with a smell of arsenic, leaving a white metallic globule; colours borax blue. The composition of this ore has not been ascertained, but it is supposed that it may be an alloy of arsenic and iron.

Gray cobalt ore is found massive, disseminated, and botryoidal; is of a light steel gray, or tin white colour, with the surface steel-tarnished. It is infusible before the blow-pipe, but emits fumes with the odour of garlic. The constituent parts are, cobalt 20, arsenic 33, iron 24, beside sometimes a small portion of nickel and silver.

Shining cobalt ore is massive, disseminated, superficial, or crystallized in the form of cubes or octahedrons, with various modifications. Colour tin white, but commonly grayish or tarnished yellow; sp. gr. 6·3 to 6·4. Before the blow-pipe it burns with a small white flame, emitting white vapour, and a garlic odour, and is soluble in nitric acid. It is composed of cobalt 37 to 44, arsenic 49 to 55, sulphur 5 to 6·5, iron 6.

This is the most common ore of cobalt, and is extracted for the purpose of being employed in the preparation of *smalt*, a fine blue pigment which is used in colouring porcelain and glass.

Black cobalt ochre exists either in an earthy form, with little coherence among the particles, or in a more compact and indurated form. It is of a brown or bluish black colour; sp. gr. 2·01 to 2·4. Before the blow-pipe it gives out the smell of arsenic, but is infusible. The constituent parts are supposed to be oxide of cobalt, with iron and arsenic.

Brown cobalt ochre is in a massive or disseminated form, and has a dull earthy aspect. The colour is liver brown of various shades, and the component parts are supposed to be oxide of cobalt and iron.

Yellow cobalt ochre exhibits nearly the same appearance and texture as the preceding, but is of a yellowish gray, or dirty straw yellow colour. It is infusible before the blow-pipe, but emits the smell of arsenic, from which it is supposed that its constituents are oxide of cobalt, with a little arsenic.

Red, earthy, or radiated cobalt ochre, arseniate of cobalt, *cobalt bloom*, or flowers of cobalt, is found either in thin superficial layers, or crusts with a dull earthy fracture, or in the form of small crystals variously aggregated. The colour is peach blossom red, rose, or crimson red; but when exposed to the air, changes to a brownish or grayish colour. Before the blow-pipe becomes black, giving out a feeble odour of arsenic, but is infusible. It communicates to borax a fine blue colour.

Sulphate of cobalt has been discovered in a stalactitical form, of a pale rose-red colour, and translucent, near Newsohl in Hungary. It was at first taken for sulphate of manganese, but being examined by Klaproth, was found to contain cobalt.

Repositories of the Ores of Cobalt.—The ores of cobalt are chiefly confined to primitive rocks, as gneiss, micaceous schistus, and others, which are disposed in beds. But the ores of cobalt are rarely found in mines peculiar to themselves; they usually accompany the ores of other metals, particularly those of bismuth, arsenic, silver, nickel, and copper. The ores of cobalt, however, do not exclusively belong to primitive rocks, as they have been met with in veins traversing those of the secondary class. Such veins are composed of heavy spar, quartz, and lime spar, and the cobalt is in the state of red, black, or gray oxide, combined with a small portion of nickel and bismuth. The secondary rocks in which cobalt is distributed, are compact limestone, gypsum, black schistus containing pyrites, and bituminous schistus containing copper, and marked with impressions of fishes.

The minerals which accompany cobalt, are such as are usually connected with the ores of metals, the veins of which are the common repository of cobalt and those ores.

It has been observed, that when veins of cobalt accompanying silver ores, unite with other veins in which the ore is ferruginous, the veins of silver ore increase greatly in mineral riches.

Mines of Cobalt.—The ores of cobalt are peculiar to European countries, and in the few places where they are found, they rarely exist in great abundance.

Britain.—Cobalt may be considered as a rare natural production of this country, as it has only been met with in one or two places, in such quantity as to render it worth the attention of extracting it.

One cobalt mine only, which deserves to be distinguished by that name, has been known in Cornwall. It was discovered accidentally in driving a level. The vein was three feet in breadth, but in carrying on the operations, the ore was soon exhausted. Some pure cobalt ore was also discovered in a copper mine, in another place in the same county. It was deposited in a small vein, from four to six inches thick, and was unmixed with other ores. It crossed a copper vein, and the cobalt ore was found in that part of the vein where it joined the other; but it very soon disappeared, or became so thin, that it was not worth pursuing. The ore is described as being of a pale red or blossom colour, so that it was probably the red cobalt ochre, or arseniate of cobalt, which was found in these mines*.

A considerable quantity of the same kind of cobalt ore was dug out a few years ago from the copper mine of Alva, near Stirling in Scotland. This was probably from the same vein which contained the mass of silver ore already mentioned in treating of the ores of silver. I have picked up some specimens of red cobalt

* Pryce, Mineralog. Cornub. p. 50.

ore, from the rubbish of the lead mines near Newton Stewart in Galloway. In this mine it seemed to be accompanied with copper ores. I do not know that cobalt ore has appeared in any other place in this country.

France.—Some indications of cobalt have appeared in the silver mine of Allemont in Dauphiné in France, as well as in some other places; particularly in the department of Vosges, where it runs in regular veins, and has for its matrix crystallized carbonate of lime; but it is not in such quantity as to render its extraction an object of pursuit. But in the valley of Luchon, in the middle of the Pyrenees, cobalt has been discovered in a vein of quartz which traverses a mountain of ferruginous schistus, and it is dug out in such abundance, that a manufactory has been established on the spot, for the preparation of zaffre and smalt.

Spain.—In the valley of Gistan, in the Spanish Pyrenees, there is a mine of cobalt, which is situated in a lofty mountain composed of a stratified rock, in which feldspar is predominant. It appears to be a species of gneiss, which alternates with beds of siliceous and micaceous schistus. Towards the middle region of the mountain, and on the west side, there is a bed of black schistus in a friable state, and often bituminous, which on the south side is 30 feet thick, and about 60 on the north side. It is supported by a bed of red feldspar on one side, and connected on the other with limestone. This bed of schistus is traversed by veins of cobalt, which run from east to west, and increase in thickness from four or five lines to more than five feet; and near the surface it yields a cobalt ore, mixed with yellow ochre and black cobalt ore. This is succeeded by brown cobalt ore, and lastly a compact ore of red cobalt, or arseniate. The sides of the vein are also penetrated with cobalt.

These veins are entirely cut off by the limestone, as well as by the bed of red feldspar. Such are the riches of some of these veins, that from 500 to 600 quintals of pure ore have been dug out.

Germany.—There are some valuable mines of cobalt at Schneeberg and Annaberg in Saxony. There is also a singular mine of cobalt at Riegelsdorff in Hessia. An immense bed of slate impregnated with copper, and marked with impressions of fishes, and which, besides, is observed to be proportionally rich in copper, as the impressions become more abundant, lies in a horizontal position, at the depth of about 200 feet. This secondary stratum of slate is covered with several beds of limestone. The whole mass of these beds contains veins, which are accompanied with regular vein stones. In these veins the cobalt is deposited, but it is only found at a considerable depth, and in the immediate vicinity of the slate, which is impregnated with copper.

Bohemia.—A considerable quantity of cobalt ore is extracted from the silver mines of Joachimsthal in Bohemia. It is frequently combined with some of the silver ores, but it is also met with in detached masses. In former times, when the demand for cobalt was less, not more than 200,000 lbs. were produced from the Bohemian mines. In the time of Baron Born, the quantity obtained amounted to 1,000,000 lbs. In more remote times, the cobalt ores, through ignorance of their value, were thrown aside among the rubbish, which has been since carefully searched, and the cobalt which is found is washed, and the greater part of it transported to Holland*.

Sweden.—The mines of cobalt at Tunaberg and Los in Sweden, are situated in narrow veins, which alternately enlarge and contract in their thickness; and from this peculiar arrangement, which seems to be pretty uniform, they have received the name of *chapelets*, chaplet or bead. The vertical section exhibits something of the appearance of that object. A similar fact has been noticed by Saussure in several places of the Alps, and particularly at the foot of mount Cenis, which he describes as an immense mass of rock, consisting of beds of limestone, separated from each other, and included in thin beds of a kind

* Born's Travels, p. 258.

of schistus; but the most remarkable circumstance is the peculiar form of the beds of limestone, each of which enlarges and diminishes successively, with a considerable degree of uniformity; the same bed being followed, is found in one place 20 inches thick, but diminishes in another, at the distance of four or five feet, to three inches. From this peculiar deposition of metallic ore, the miners entertain the opinion, that the metallic particles which compose the veins have gradually occupied the place of the particles of stony matter; and this opinion is considered by some geologists as probable; according to which, it is supposed that the earthy matter of the rock has been converted into veins of cobalt.

SECT. XIII.

ORES OF NICKEL.

Nickel is of a shining white colour like that of silver, and of a granulated texture. The sp. gr. after fusion is 8·2; but after being hammered, it is 8·6. Nickel possesses some degree of malleability, and, like iron, it is attracted by the magnet.

Ores of Nickel.—The ores of nickel are few in number. Two only have been discovered, the one in the state of alloy, and the other in the state of oxide.

Copper-coloured nickel, kupfernickel, or false copper, is found massive or disseminated, and of a pale copper red, whitish, or grayish colour; sp. gr. 6·6 to 7·5. Before the blow-pipe it gives out the fumes and odour of arsenic, and melts with difficulty into a slag mixed with metallic particles. The solution in acids is green, and the constituent parts are, nickel 75, arsenic 22, sulphur 2. But beside these ingredients, it sometimes contains also iron, cobalt, and even bismuth.

Nickel ochre, or oxide of nickel, is commonly found efflorescent on other minerals. It is usually in a loose friable state; the colour, apple green of various shades; before the blow-pipe it remains unchanged, but communicates to borax a yellowish red colour. It is insoluble in nitric acid. The constituent parts are, oxide of nickel 67, oxide of iron 23, water 2.

Repositories, &c. of Nickel.—The ores of nickel commonly exist in veins, along with other metallic ores, and particularly in veins of silver, copper, or cobalt. It belongs exclusively to the primitive class of rocks; its usual matrix is quartz, heavy spar, and lime spar. It is rarely met with in large masses.

The mines of Allemont, in Dauphiné in France, furnish copper-coloured nickel. It is accompanied by a silver ore, to which it communicates a green colour. The same species of nickel ore exists in some mines of the Pyrenees. It is also not very uncommon in the silver mines of Freyberg in Saxony, and Saalfield in Thuringia, where it accompanies gray silver ore. In the mines of Joachimsthal in Bohemia, this ore of nickel appears in a dendritical form, in a matrix of quartz.

The other ore of nickel, the oxide, is rarely found in masses, for it usually accompanies copper-coloured nickel, and sometimes exists in intimate combination with other minerals, to which it communicates a green colour. The existence of nickel in the masses of iron found in Siberia and in South America, and in all the meteoric stones which have been examined, has already been noticed in the remarks on native iron.

SECT. XIV.

ORES OF MANGANESE.

It has been hitherto found extremely difficult to extract manganese from its ores, and reduce it to the metallic form. In this state it is of a grayish white colour, of a granular texture, possesses considerable brilliancy, equals iron in hardness, but is very brittle; sp. gr. 6·8. It is only fusible at the temperature of 160° of Wedgwood.

Ores of Manganese.—The ores of manganese, which exist chiefly in the state of oxide, and sometimes in that of carbonate, appear under a great variety of forms; but it is easy to detect a notable quantity of that metal by means of the blow-pipe, by the action of which it produces with borax, and with the addition of a little nitre, a violet coloured glass.

Gray ore of manganese, or oxide of manganese, is found in a radiated, foliated, compact, and earthy form, the essential character of all which is, that it colours borax violet. The radiated ore is massive or disseminated, or crystallized in oblique four-sided prisms, or in acicular prisms, in fascicular groups. The colour is steel gray, or iron black; sp. gr. 3·7 to 4·7. The foliated gray ore is also found massive, disseminated, or crystallized; the compact gray ore is found massive or disseminated, in angular, botryoidal, or dendritical forms. The colour is steel gray, or bluish black. The earthy gray ore is also massive and disseminated, and sometimes superficial and dendritical, with a dull earthy fracture.

The constituent parts of the varieties of the ores of manganese now enumerated are, oxide of manganese 83 to 99, oxide of iron 2 to 3, carbonate of lime 7·5, barytes 1·5 to 3, silica 5 to 7; but it must be observed that these ingredients appear to exist in very variable proportions; some of them are entirely wanting; and purer specimens of the ore which have been examined, consist only of oxide of manganese 92 to 99, with a small quantity of water.

Black ore of manganese is found in a massive, disseminated, or crystallized form, the crystals being four-sided double pyramids, arranged in rows; is of a grayish or brownish black colour, and gives a dull brownish red streak. It is composed of oxide of manganese 82, carbonic acid 5, and sulphur 11; and some specimens contain a considerable proportion of barytes in a state of purity.

Red ore, or carbonate of manganese, exists massive, disseminated, botryoidal, or crystallized in small pyramids, or flat rhomboids; is of a rose red, or brownish white colour; sp. gr. 3·2. Infusible before the blow-pipe, but becomes grayish black, and colours borax violet blue, or crimson red. The constituent parts of this ore are, oxide of manganese 48, oxide of iron 2, carbonic acid 49, with a small proportion of silica.

The phosphate of manganese has been already mentioned under the name of *pitchy iron ore*, among the ores of iron, although it more properly belongs to those of manganese, since the proportion of the latter is greater than the proportion of iron; and besides, it appears that the iron is only an accidental combination, and the phosphoric acid is united with the manganese only.

Repositories of the Ores of Manganese.—Manganese is universally diffused through all kinds of rocks; but when it is met with in masses, or in considerable quantity, it is deposited chiefly in veins which traverse primitive rocks. The oxide of manganese frequently accompanies the ores of iron, and particularly sparry iron ore; it is found in veins along with red and brown iron ores. It appears in a dendritical form, between the layers of malachite, mountain cork, and some other minerals, and sometimes it is met with in intimate combination with cobalt. Oxide of manganese is not uncommon in a dendritical form, in stone marl, some of which is susceptible of a considerable polish, thus exhibiting black shining arborescent figures. The ores of manganese are frequently accompanied by sulphate of barytes, as well as some other earthy and stony bodies.

Mines of Manganese.—It has been already observed, that manganese is very universally diffused. It is accordingly met with in smaller or greater proportion, accompanying other metallic ores, and particularly those of lead and iron. But the ores of manganese also exist in considerable detached masses, either in the form of veins or beds, in different parts of the world.

Britain.—Although the ores of manganese may be considered as no uncommon productions of many of the mines of Britain, yet there are not many places where they are in such abundance, as to come under the denomination of mines of manganese. Upton-Pyne in Devonshire is, I believe, the principal source from which the oxide of manganese, now become so valuable in various manufactures, is derived, to supply the demand of this country. The discovery of manganese at that place was made about 40 years ago. The ore, it is said, does not run in veins, but is deposited in flat, irregular patches, at no great depth from the surface. The beds of manganese extend from Upton-Pyne south-east to Huxham, and north-west to Newton St Cyres. It is dug out in large, rugged, irregular masses, the cavities and fissures of which contain numerous crystallizations. Some years ago, 200 tons of manganese were exported annually, and the price it brought was from 30s. to L. 3 *per* ton *. It is scarcely necessary to mention, that this oxide of manganese is employed chiefly to discharge the colour of crystal glass, when used in small quantity, or in larger quantity, to communicate to glass a violet colour; as a pigment in the manufacture of porcelain ware; and in the preparation of oxymu-

* History of Exeter, p. 93.

riatic acid, now of such extensive application in the processes of bleaching.

Excepting in one place, the ores of manganese have not been met with in Scotland in such quantity as to become an object of pursuit. A considerable vein of manganese was discovered some years ago in the primitive rocks of Aberdeenshire, and a good deal of the ore was dug out; but the ore is so extremely hard, arising probably from the stony matters, particularly quartz and heavy spar, with which it is mixed, or perhaps from a large proportion of silica with which it is intimately combined, that it was found difficult to reduce it to the state of powder, so that it could not be applied to the ordinary purposes of that ore. This mine afforded some beautiful specimens of the radiated gray ore.

France.—This kingdom possesses some valuable mines of manganese; and one which is described as the most interesting, is that of Romaneche, in the department of Saone and Loire. This mine is situated on the eastern declivity of a chain of primitive mountains, which stretch from north-north-east, and are composed of granite, limestone, and a siliceous sandstone. The granite, incumbent on which is the manganese, is seen at Romaneche. This mine, according to Dolomieu, by whom it is described, forms neither a bed nor a vein, but is deposited in a kind of accumulated mass, about 10 fathoms in its greatest breadth, and nearly 200 in length; it extends from north-east to south-west, nearly parallel to the chain of mountains. It appears on the surface, and even rises above the vegetable soil at its northern extremity; but in proceeding to the south-west, it sinks under the stratum of clay and sandstone. On the south-east flank it is bounded by a stratum of limestone immediately incumbent on the granite; but on the north-east flank, the granite itself forms the limit, and seems to have cut it off entirely. The thickness of this mass of manganese is from 7 to 15 feet. The greatest part of the mass is free from mixture of other minerals; sometimes, however, it is combined with fluor spar of a deep violet colour, and the cavities and fissures contain a fine ductile clay of a reddish gray colour *.

Manganese is also met with in other places of France, and particularly in the Cevennes, where it is found in a matrix of granite. The ore is light and friable, and divides in irregular prisms, somewhat in the manner of basalt. It is also met with in the department of Vosges, and in that of Moselle. The compact variety of the gray ore is dug out in considerable quantity in the vicinity of Perigueux, in the department of Dordogne,

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* Jour. des Mines, No. xix. p. 27.

and is known in commerce by the name of Perigueux stone.

The following is a description of the manganese mine of St Marcel, in the valley of Aoste in Piedmont, by Saussure *. This mine is situated in a mountain of gneiss, the beds of which are nearly in a horizontal position. The mine is entirely open to the day, and the ore is supposed to be deposited in the form of a large mass, rather than in that of a bed or vein. It lies parallel to the strata of the mountain, and is about 15 feet in thickness, where it appears on the surface, but gradually diminishes as it enters the mountain, to the thickness of five or six feet. It has been penetrated about 50 feet, and it does not appear to exceed 200 or 300 feet in length. Its inclination from the west is at an angle of 15° or 20°. This mine affords fine specimens of the red ore, or carbonate of manganese, which are of a beautiful purple red colour, and crystallized in the form of rhomboidal prisms.

Germany, &c.—The ores of manganese are not uncommon in different parts of Germany. The red ore, or the carbonate of manganese, has been found in the gold mine of Nagyag, and other auriferous mines in Transylvania. Patrin mentions a siliceous sandstone, which is found in an iron

* Voyages, § 2294.

mine in the Uralian mountains, and which is entirely penetrated with manganese, disposed in a dendritical form, through the whole mass of the stone. The fissures of the sandstone are lined with thick incrustations of the same mineral, in the form of rays, of an inch in diameter.

SECT. XV.

ORES OF ARSENIC.

ARSENIC is a metallic substance of a very brittle, and even friable nature; of a black colour, and with a fresh fracture, of a brilliant appearance; but is soon tarnished by exposure to the air. The fracture is granulated, and sometimes a little foliated, or splintery; sp. gr. 8·3.

Arsenic burns with a bluish flame; and under whatever form it appears, it may be readily distinguished by its white fumes, and the peculiar odour of garlic which it emits when heated. This smell is very pungent, and when once perceived, can scarcely be confounded with that of any other substance.

Ores of Arsenic.—Arsenic, in the state of ore, exists in all the different forms in which metallic ores are usually found, as in that of native arsenic, in the state of sulphuret, in that of oxide, and in the state of salt.

Native arsenic is found massive or disseminated, having a rough or granulated surface; colour light lead gray, tin white, or grayish black when tarnished; sp. gr. 5·72 to 5·76; which is considerably inferior to that of the pure metal artificially prepared. It melts readily before the blow-pipe, emitting a white vapour, with the odour of garlic. Native arsenic is usually alloyed with a little iron, and sometimes also with a small portion of gold or silver; and when the arsenic is volatilized by means of heat, these substances remain behind in the form of scoriæ.

Arsenical pyrites, or mispickel, is divided into two varieties, common and argentiferous, the latter distinguished from the former by containing a quantity of silver, which varies from 1 to 10 *per cent.* The first variety is found massive or disseminated, and also crystallized in oblique four-sided prisms, which are usually small, and variously modified on their angles, faces, and extremities. The colour is silvery white, and often tarnished yellow, or bluish and iridescent; sp. gr. 5·7 to 6·5. When rubbed, it gives out the odour of garlic, and before the blow-pipe a white vapour appears, having the usual odour. It is composed of arsenic, iron, and sulphur. The second variety is also found massive or crystallized, in small acicular four-sided prisms, of a tin or silvery white colour, but is also usually tarnished.

Orpiment, or sulphuret of arsenic, is also divided into two varieties, yellow orpiment, and red orpiment, or realgar. Yellow orpiment is found massive, disseminated, superficial, or crystallized in oblique, four-sided prisms. The crystals are small, with a smooth surface, and are confusedly aggregated. The colour is citron or golden yellow, and sp. gr. 3·3 to 3·4. Before the blow-pipe it gives out a blue flame with white vapour, and the smell of arsenic and sulphur. The constituent parts of this ore are, arsenic 80 to 84, sulphur 16 to 20; but according to Thenard, it is composed of sulphur 43, and arsenic 57.

Red orpiment, or realgar, is rarely found massive, but is usually disseminated or superficial, and often crystallized in oblique four-sided prims, with obtuse lateral edges. The colour is light aurora red, scarlet red, or orange yellow; sp. gr. 3·2. It is supposed that this variety contains a smaller proportion of sulphur, and is contaminated with iron and silica; but the analysis of Thenard determines the proportions to be, sulphur 25, and arsenic 75. Perhaps this was a purer specimen of the ore.

Oxide of arsenic is an ore which usually exists in an earthy and friable form, and is attached to the surface of other minerals; sometimes it is crystallized in capillary crystals, or small octahedrons, The colour is snow white, yellowish, reddish, or grayish white; sp. gr. 3·7; is entirely dissipated before the blow-pipe, and is soluble in water and acids. This ore, which is a rare mineral production, is a pure oxide of arsenic, containing an accidental mixture of earth.

Arsenic combined with such a proportion of oxygen to convert it to the state of acid, is found in nature united with various metallic and earthy substances, forming salts, as arseniate of lime, which is found in small capillary crystals, with a silky lustre and radiated fracture. Colour snow white; sp. gr. 2·5 to 2·6. Soluble in nitric acid with effervescence, and is composed of arsenic acid 50·5, lime 25, water 24. Arsenic acid also enters into combination with copper, iron, lead, and cobalt, which have been already described among the ores of those metals.

Repositories of the Ores of Arsenic.—The ores of arsenic are usually distributed in primitive rocks. Some of them, however, as the yellow orpiment, exist in stratified mountains. But arsenic is more commonly found along with the ores of other metals, and particularly those of silver. This is the peculiar repository of native arsenic.

Realgar is met with in primitive rocks, but it may be considered also as a volcanic production, being frequently found sublimed in the crater of volcanoes, or in the fissures of the lava. The ores of other metals are sometimes succeeded by those of arsenic in going downwards. It has been already noticed, in treating of the mines of mercury in South America, that at the depth of 600 fathoms the ores of arsenic were found occupying the place of a vein of cinnabar, and were dug out for that ore; and in the silver mine of Zmeof in Siberia, at the depth of 96 fathoms, the only ore found in the vein was native arsenic; and indeed, according to Patrin, the veins of silver ore in Siberia, in going downward, generally terminate in arsenical ores.

Arsenic in such abundance, or in that state in which it comes under the denomination of an ore of that metal, is rarely found in Britain; but in the form of arsenical pyrites, it is not uncommon in Cornwall; and in combination with other metals, or, according to the old form of expression, as a mineralizer of other metals, it is met with in greater or smaller proportion in almost all mines. Thus, the arseniates of copper were formerly frequent productions of the Cornwall mines; and thus, too, the arseniates of lead and of cobalt are occasionally met with in other places.

Native arsenic is found at the mines of St Mary in France, in a vein which uniformly contains that ore, between the hanging side of the vein, which is a rock of schistus, and the matrix, which is lime spar; at Freyberg in Saxony, it exists in rounded masses, composed of concentric layers, and containing about 4 *per cent.* of silver.

Arsenical pyrites is abundant in almost all the silver and tin mines in Saxony and Bohemia; in that part of the Pyrenees called Couserans, a vein of arsenical pyrites has been discovered, which is included in rocks filled with the same pyrites; from which it has been inferred, that veins of cobalt or of tin might be discovered in its vicinity.

The oxide of arsenic has been found in Hessia, Saxony, and Hungary, and in a mine of cobalt in the valley of Gistain, in the Spanish Pyrenees. It is met with also in the mines of Transylvania and Bohemia; at Joachimsthal in the latter country, it appears in the form of quadrangular prisms, attached to heavy spar, or argillaceous schistus; but this is a rare mineral. The oxide of arsenic is sometimes, but rarely, met with in the form of a white efflorescence, either in the veins of the other ores of arsenic, or sublimed in volcanic rocks.

Realgar is deposited in primitive rocks, as at St Gothard; and in that variety of limestone called *dolomite*, in a place mentioned by De Born, on the borders of Transylvania, occupying a vein of a foot in thickness, which consists entirely of realgar, which is friable, and of an earthy appearance. In the gold mine of Nagyag in Transylvania, it is in irregular masses, and accompanies auriferous ores. At Felsobanya in Hungary, and in some of the mines of Bohemia and Saxony, realgar exists in the form of quadrangular prisms.

This ore of arsenic is also a volcanic production. It is found at Solfatara near Naples, in the fissures of volcanic rocks, under the form of small octahedral crystals, somewhat like rubies. At Vesuvius, in the current of lava which was ejected from that volcano in 1794, it is also crystallized. Ætna in Sicily also affords realgar. The same ore is the production of a volcano in Japan, and of another in Guadaloupe in the West Indies; it is distinguished by the name of red sulphur.

Although orpiment frequently accompanies the former ore of arsenic, yet it is considered as rather belonging to stratified rocks. This ore of arsenic is also met with in the crater of volcanoes, along with sulphur, sal ammoniac, and other volcanic productions. Orpiment, however, is found in some of the mines of Hungary and Transylvania, in nests, and even in veins, and particularly in mines of copper and silver. It is found at Tayoba in Hungary, in small detached masses, consisting of octahedral crystals confusedly grouped together, and imbedded in a bluish clay; and in the mine of Ohlalapos in Transylvania, it is in the form of small testaceous masses, aggregated like roe-stone. A great deal of the orpiment of commerce comes from the Levant, and other eastern countries, in the form of irregular masses, with a foliated texture.

SECT. XVI.

ORES OF MOLYBDENA.

MOLYBDENA has never yet been completely reduced to the metallic state, so that its peculiar characters, as a pure metal, are unknown; but it is supposed that its specific gravity is about 6, or, according to others, 6·9. It is of a steel gray colour, of a compact, unequal, and somewhat granulated texture.

Ores of Molybdena.—The only ore of molybdena is that of the sulphuret, which is found massive or disseminated, sometimes laminated, or in plates, and rarely crystallized in equal six-sided tables, like the crystals of mica. It possesses a shining lustre, and a foliated fracture. The colour is lead gray; it is very soft, and in thin plates is flexible; feels greasy; sp. gr. 4·5 to 4·7. It is infusible before the blow-pipe, but gives out a sulphureous smell. Nitric acid converts it to a white oxide, which is the molybdic acid. The constituent parts of this ore are, molybdic acid 45 to 60, sulphur 40 to 55.

The only other mineral of which this metal forms a component part, is the molybdate of lead, already described under the ores of that metal, and chiefly obtained from Bleyberg in Carinthia.

Repositories, &c. of Molybdena.—The sulphuret of molybdena may be considered as a rare mineral production. It is usually found in small detached masses, in veins of quartz which traverse granite mountains, and accompanied with tin ores, wolfram, quartz, native arsenic, and fluor spar.

The ore of molybdena is met with only in this country in the western parts of Inverness-shire in Scotland, where it is deposited in chlorite schistus, and accompanied by common actynolite. In France, in the neighbourhood of Mont Blanc, it is disseminated in small plates near gray granite; in Saxony it is imbedded in quartz, mixed with a greenish stone marl; at Zinnwald in Bohemia, it exists also in a greasy opaque quartz; and at Schlakenwald in the same country, it is found in large plates in a transparent quartz. According to De Born, an argentiferous ore of molybdena has been found in Hungary, in rounded masses of two inches in diameter, deposited in a grayish coloured clay. The masses are composed of large shining plates applied to each other. The proportion of silver with which it is combined, amounts nearly to 12 *per cent.* Molybdena has also been found in Upper Hungary, in a state of combination with gold.

SECT. XVII.

ORES OF TUNGSTEN.

TUNGSTEN is one of the metals which, in its combination with oxygen, performs the part of an acid. The acid form of this metal was discovered by Scheele in 1781. It was reduced to the metallic state by the brothers Delhuyarts. This metal is of a grayish white colour, very hard, very brittle, and assumes the crystallized form. The sp. gr. is said to be 17·6.

Ores of Tungsten.—The only two ores of tungsten known are in the state of salt, which are wolfram and tungstate of lime.

Wolfram is found massive, disseminated, or crystallized in six-sided prisms, and in rectangular four-sided tables; colour brownish black, or perfect black, and sometimes tarnished; it is soft and brittle; sp. gr. 7·1 to 7·3; decrepitates before the blow-pipe, but is infusible. The constituent parts of this ore are, tungstic acid 35 to 67, oxide of manganese 7 to 32, oxide of iron 13 to 31, and sometimes a small portion of silica.

Tungsate of lime, or tungsten, is also found massive, disseminated, or crystallized in regular octahedrons. Colour grayish or yellowish white, translucent, brittle; sp. gr. 6·06; decrepitates before the blow-pipe, and loses its transparency, but is infusible. When reduced to powder, and digested with nitric or muriatic acid, a citron yellow residuum is produced, which is tungstic acid. The constituent parts are, oxide of tungsten 75 to 77, lime 17 to 18, silica 1 to 3, with a small portion of oxide of iron and manganese.

Repositories, &c. of the Ores of Tungsten.—The ores of this metal belong exclusively to primitive rocks, and very frequently they accompany the ores of tin.

Cornwall is the only place in Britain in which the ores of tungsten have been discovered, and there they are mixed with ochre of iron, and other metallic substances. Tungstate of lime has been found in the department of Isere in France, and wolfram is said to be abundant in a vein of quartz near St Leonard, in the department of Upper Vienne.

In examining the mountain where the wolfram is found, three powerful veins of white quartz, from four to five feet in thickness, and running from north-east to south-west, were discovered. In one of these veins, the top of a vein of wolfram, ten inches thick, was observed.

Both the ores of tungsten have been found in Saxony and Bohemia, where they also accompany the ores of tin. Tungstate of lime, in small octahedral crystals, of a yellowish brown colour, is met with at Zinnwald in Bohemia, attached to quartz or mica.

Wolfram has been found only in one place in Siberia, in the mountain of Odon-Tchelon in Daouria. It is deposited in the fissures of granite, where it is always accompanied with topazes and beryls. The matrix of the wolfram is a granulated quartz, in which are disseminated the minerals just mentioned; and it is also mixed with changeable coloured mica, and insulated crystals of blende. Some of the ores of tungsten have also been met with in Sweden.

SECT. XVIII.

ORES OF TITANIUM.

TITANIUM has never yet been completely reduced to the metallic state. A thin friable pellicle of the colour of copper has only been obtained.

Ores of Titanium.—The ores of this metal which have been hitherto discovered, are always in the state of oxide.

Menachanite is usually found in small detached rounded grains, with a rough surface, and semi-metallic appearance. It has also been met with massive; colour grayish, or iron black; sp. gr. 4·4; infusible before the blow-pipe, but colours borax greenish brown. Constituent parts are, oxide of titanium 40 to 45, oxide of iron 49 to 51, silica 3 to 11, and sometimes a portion of manganese. The massive form of this ore retains a larger proportion of iron, and less of titanium.

Octahedrite is only met with crystallized, in elongated octahedrons with square bases; colour steel gray, sometimes light indigo blue; sp. gr. 3·8; infusible before the blow-pipe, but melts with borax, which it colours green, and in cooling crystallizes in the form of needles. This ore is chiefly composed of oxide of titanium.

Titanite, or red schorl, is crystallized in oblique four-sided prisms; it exists also in acicular and capillary crystals, imbedded in quartz, or grouped together; colour blood red, or reddish brown; sp. gr. 4·1 to 4·2; infusible before the blow-pipe, but loses its transparency. This ore is also chiefly composed of oxide of titanium.

Nigrine is found disseminated, and sometimes amorphous, but often crystallized in oblique four-sided prisms; colour dark brownish black, or violet brown; sp. gr. 3·5 to 4·6; infusible before the blow-pipe. Constituent parts, oxide of titanium 33 to 74, silica 8 to 35, lime 18 to 32.

Iserine exists in rounded or angular grains, having a rough and glimmering surface; colour iron black, or brownish; sp. gr. 4·5.

Repositories, &c. of the Ores of Titanium.—The ores of titanium have been only found in primitive rocks. The only ore of this metal which has been discovered in Britain is the first, or menachanite, which is met with in the valley of Menachan in Cornwall, and in the form of sand. It is said that almost all black sands contain a portion of titanium. A sand of this description from Providence, one of the Bahama islands, and from Botany Bay in New Holland, has been found to contain a portion of this ore. Nigrine is found in different places in France, as in the mine of Allemont, in the rocks of Mont Blanc, and in those of the neighbourhood of Limoges, in a quarry to the west of Nantz, where it is in the form of small gray crystals, between two layers of hornblende, in feldspar. Titanite has been also found in France, in the neighbourhood of Limoges, in alluvial soil; and in the department of Mont Blanc, it has been met with in a vein traversing a mountain composed of greenish, or whitish talcky schistus. This vein contains quartz, lime spar, sparry and specular iron ore; and the titanite is deposited in the cavities of those stones, in acicular crystals grouped together. The same ore has been met with in many other countries, as in Spain, Germany, in New Spain, where it is in the form of large crystals in quartz, and also in South Carolina. Some of the ores of titanium have been found in Westmania in Sweden, in a matrix of talc and quartz, mixed with tourmaline.

SECT. XIX.

ORES OF URANIUM.

LITTLE is known of the peculiar characters of uranium. It is described as of a deep gray colour, and so soft that it may be cut with a knife; sp. gr. does not exceed 6·4. Uranium is soluble in nitric acid, and the oxide communicates to glass a deep orange colour. This metal is very difficult to reduce, and is almost infusible.

Ores of Uranium.—The ores of uranium which have hitherto been discovered, are always in the state of oxide.

Pitchy ore of uranium is found massive, disseminated, and sometimes cellular; of a velvet or iron black, or bluish colour; sometimes steel tarnished, streak black; sp. gr. 6·5 to 7·5; soluble in nitric acid, but infusible before the blow-pipe. Constituent parts are, uranium slightly oxidated 86, sulphuret of lead 6, oxide of iron 2, silica 5.

Micaceous uranite exists in thin layers, and is also often crystallized in rectangular four-sided tables, or in cubes. The crystals are small and grouped together; the colour is emerald, or grass green of various shades; sp. gr. 3·12; soluble in nitric acid, and communicates a citron yellow colour; composed of oxide of uranium with a little copper.

Uranite ochre is usually disseminated or superficial, but is also sometimes found massive; colour citron yellow, or aurora red; sp. gr. 3·1 to 3·2; composed of oxide of uranium, with a small portion of iron.

Repositories, &c. of the Ores of Uranium.—The ores of uranium have been found only in primitive rocks, and they neither exist in great abundance, nor are they very generally diffused over the globe.

The first species, or the pitchy ore of uranium, is met with in small masses in veins, with lead, copper, and silver, at Joachimsthal in Bohemia, and also in Saxony. The other species are also found in Saxony, and in Wurtemberg, along with earthy cobalt ore. The pitchy ore exists in France, in a vein of friable granite, and it has been met with in Cornwall in England, along with arseniate of copper.

SECT. XX.

ORES OF TELLURIUM.

Tellurium resembles antimony in many of its characters. It is of a brilliant white colour, of a foliated texture, very brittle, and very fusible. In cooling, it exhibits on the surface a radiated crystallization; sp. gr. 6·1; it leaves a black trace on paper. It burns easily with a blue flame; the oxide is white; it is volatile, and emits a peculiar odour, which resembles that of radishes. It is precipitated from its solutions by antimony.

Ores of Tellurium.—Tellurium exists in its ores only in the state of alloy.

Native tellurium is found massive or disseminated, having a shining metallic appearance, and foliated fracture; the colour is between tin and silvery white, and the sp. gr. 5·7 to 6·1. It melts readily before the blow-pipe. Constituent parts are, tellurium 92·6, iron 7·2, gold 0·2. This ore has been called *aurum paradoxum*, and *problematicum*, because its external appearance affords no indication of its containing gold.

Graphic ore of tellurium is found massive, or crystallized in flat four or six sided prisms, which are arranged in rows, and exhibit something of the appearance of written characters, from which it derives its name; colour tin white, yellowish, or lead gray; sp. gr. 5·7 *; before the blow-pipe it burns with a greenish flame. Constituent parts are, tellurium 60, gold 30, and silver 10.

Yellow ore of tellurium is also found disseminated, or crystallized in small four-sided prisms; colour a silvery white, yellowish, or gray; sp. gr. 10·6; soluble in nitric acid. Constituent parts, tellurium 45, gold 26, lead 19, silver 8, sulphur 0·5.

Black, or foliated ore of tellurium, exists in plates which are formed in masses, or disseminated, and rarely crystallized in six-sided tables; colour between lead gray and iron black; sp. gr. 8·9. Before the blow-pipe the sulphur and tellurium are dissipated in white fumes, and a metallic globule, surrounded by a black slag, remains. Constituent parts are, tellurium 33, lead 50, gold 8·5, silver and copper 1, sulphur 7·5.

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* The sp. gr. here stated is the same in all the books which I have consulted; but from the great proportion of gold in the ore, it is undoubtedly too low.

Repositories, &c. of Tellurium.—Excepting some indications of native tellurium, which have been observed at Beresof in Siberia, the mines of Facebay, Offenbanya, and Nagyag, in Transylvania, are the only places which have hitherto furnished ores of tellurium. The ore called native tellurium is dug out at Facebay, for the purpose of extracting the gold, although it contains but a small proportion. It is got from veins, which traverse compact limestone, and a variety of gray wacken breccia. The graphic ore of tellurium has been found only at Offenbanya, forming veins with iron pyrites, blende, and gray copper ore, which traverse a mountain composed of syenite, porphyry, and limestone. The yellow ore is met with only in the mines of Nagyag, where it is treated as a gold ore. It exists in the same matrix with the other ores, and is accompanied by the same minerals, and also by the rose-coloured siliceous ore of manganese.

SECT. XXI.

ORES OF CHROMIUM.

This substance is almost unknown in the state of pure metal, as it is found extremely difficult to reduce it, and it is almost infusible. It crystallizes in the form of small needles, which are fascicular and very brittle; but chemists are more familiar with the oxide of this metal, which communicates to glass a beautiful green colour, that remains unaltered in the greatest heat. The oxide also assumes a fine orange red colour with nitric acid.

Ores of Chromium.—This metallic substance is to be considered rather as in combination with the ores of other minerals, than as constituting a separate division of itself. Two ores only have been described as peculiar to chromium.

Needle ore is found in small crystals imbedded in quartz, and having a shining lustre; colour steel gray, with a greenish efflorescence. The constituent parts of this ore have not been precisely determined, but it is supposed to be an alloy of chromium with some other metal.

Ochre of chromium exists massive, disseminated, or in thin plates, of a verdigris green, or yellowish colour. This is probably an oxide.

An oxide of chromium combined with an oxide of lead, has been met with in the form of small needles, or in powder disseminated on the matrix, and even on the crystals of chromate of lead. This ore is of a pure green colour, which it communicates to borax, and which remains unaltered by heat. It gives a red orange colour to nitric acid.

The chromates of iron and lead have been already described, as well as the repository of the latter, which is a clay, or sandstone, resembling gneiss, or in a matrix of quartz, in a lead vein at Beresof in Siberia. The chromate of iron was first discovered near Grassin, in the department of Var in France. It was found in the soil of the valley, and afterwards in its native repository, which is a serpentine rock, and in which it is sparingly distributed in nodules. It has been since found also in the Uralian mountains.

Chromium has been detected in the state of green oxide in the emerald, in smaragdite, and in some varieties of serpentine, and in small proportion in meteoric stones. In the state of acid it exists in spinel ruby, and also in combination with lead and iron.

SECT. XXII.

ORES OF COLUMBIUM.

The properties of this metallic substance are only known in the state of oxide, which is of a white colour, and acts the part of an acid. It combines with alkalies, and with sulphuric and muriatic acids when heated. It is precipitated from its acid solutions, of an olive green colour, by prussiate of potash, and of a deep orange by tincture of galls. The hydro-sulphuret of ammonia produces a precipitate of a chocolate brown colour from its alkaline solutions.

The only ore of this metal yet known is an oxide of columbium and iron; and indeed, a single specimen only of the ore has been discovered. It was found by Mr Hatchett in the collection of Sir Hans Sloane, and is described as being brought from Massachussets in North America. This ore, which was examined and analysed by that chemist, has some resemblance to chromate of iron. It is of a deep gray colour, has a granulated fracture in one direction, and slightly foliated in the other; the lustre of the fresh fracture is shining; sp. gr. 5·9. Constituent parts are, oxide of columbium 78, oxide of iron 21.

SECT. XXIII.

ORES OF TANTALIUM.

The peculiar properties of tantalium, as a pure metallic substance, are unknown. The oxide is white, and is unaltered by heat, gives no colour to borax, and is entirely insoluble in acids, but it is slightly soluble in the pure fixed alkalies; sp. gr. of this oxide is 6·5.

Two ores of this metal only are known. Tantalite is met with crystallized in octahedrons, which have a smooth surface and a compact fracture; colour bluish gray, or black; sp. gr. 7·9; and the constituent parts are tantalium, iron, and manganese.

Yttrio-tantalite exists in small disseminated masses, about the size of a nut; is of a deep gray metallic colour; may be scratched with a knife; the powder is gray, and the sp. gr. 5·1. This mineral is composed of iron, manganese, tantalium, and the new earth yttria.

The first ore of this metal has been only met with in Finland, disseminated in globular masses, in a vein composed of red feldspar, which traverses a gneiss mountain. The other ore is found deposited in the same vein of feldspar which contains the mineral called gadolinite, at Ytterby in Sweden.

SECT. XXIV.

ORES OF CERIUM.

Cerium has never been reduced to the metallic state; but in the state of oxide two degrees of oxidation have been observed. In the first, the oxide is white, and dissolves readily in acids; the solution is of a rose-red colour. The other oxide is red, and is soluble only in muriatic acid, giving out during the solution oxymuriatic acid. The solutions of this oxide are reddish; the oxides of cerium are insoluble in pure alkalies; the acid solutions are precipitated of a white colour by the prussiates, and by all the alkalies, and of a yellow colour by gallic acid; the white precipitates become red by calcination. Sulphurated hydrogen throws down the solutions of this metal in the form of a white precipitate, but does not afterwards combine with it.

Cerite, or the siliceous oxide of cerium, is the only ore of this metal yet discovered. It is found massive or disseminated, having a weakly glimmering lustre, and a fine grained even fracture; the colour is pale rose red, and the sp. gr. 4·5 to 4·9. It is infusible before the blow-pipe, and produces no change of colour in borax. Constituent parts are, oxide of cerium 54, oxide of iron 4, silica 34, water and carbonic acid 5, and sometimes a small portion of lime.

The only repository of this ore is the copper mine of Bastnaes at Riddarhytta in Sweden, where it is accompanied by copper, molybdena, bismuth, mica, and hornblende.

CHAP. V.

OF EARTHQUAKES AND VOLCANOES.

The preceding chapters have been occupied in a brief detail of the constitution, relative position, and connection of the various materials of which the globe of the earth is composed, so far as they have been subjected to the limited researches of man. Having hitherto contemplated nature in a state of seeming repose, we are now to consider some of those changes which are supposed to have taken place in the distribution and arrangement of the materials of the earth, or the theories which have been proposed to account for those changes; but as earthquakes and volcanoes present too prominent and too striking features in the history of the earth to be passed over entirely unnoticed, I propose, 1. To take a comprehensive view of those sudden changes which are exhibited in the devastation and ruin which accompany the earthquake and the volcano;—changes, of which the very contemplation is impressive and awful, but the desolating effects are dreadful and terrible.

Many of the phenomena of earthquakes and volcanoes are common to both. Earthquakes not unfrequently precede, and sometimes accompany volcanic eruptions; but, on the other hand, earthquakes have often existed, and their terrible effects have been severely and extensively felt, where no volcano was ever known.

SECT. I.

OF EARTHQUAKES.

Although earthquakes have been felt in most countries of the world, yet there are particular spots which are peculiarly subject to this dreadful calamity; and this seems to be independent of local circumstances, or particular regions of the globe. It has been observed, that earthquakes are more frequent within the tropics. There are, however, places within the torrid zone, which are more rarely visited by earthquakes than some of the more temperate regions of the earth. The islands of the West Indies, and some parts of the American continent which lie between the tropics, have more frequently experienced the effects of earthquakes than most other regions; but the northern shores of the Mediterranean, the kingdom of Portugal, and some other places without the tropics, have oftener exhibited scenes of desolation by the visitation of earthquakes, than many of the islands and extensive continents within the torrid zone. Thus it appears that earthquakes are not limited to particular regions; and neither proximity of place to the equator, or to the poles of the earth; neither insular situation, nor extent of continent,—affords security or exemption from their terrible effects. But at the same time it must be observed, that particular islands, and particular parts of continents, are peculiarly subject to earthquakes. No island in the West Indies has more frequently experienced their dreadful effects than the island of Jamaica. Scarcely a year passes without several shocks being felt. Mexico and Peru are oftener the scene of earthquakes than the other regions of the American continent; and Portugal has been often shaken to its very foundations by terrible earthquakes, while Spain, immediately contiguous, is almost exempted from their effects. Earthquakes, it has been observed, have proved less destructive in Italy than in Sicily, which are in the immediate vicinity of each other, and are both volcanic countries.

It is scarcely to be expected, that observations on phenomena so awful and terrible can be very numerous or precise. The operation of the causes by which they are produced, is too rapid and violent, and the effects are too sudden and unexpected, to become the subject of accurate or attentive philosophical investigation; or perhaps it might be at once acknowledged, that they exceed the comprehension of the powers of man.

Earthquakes are more frequent in volcanic countries than in any others. When a volcano has ceased to emit flame and smoke for any long period, shocks of earthquakes begin to be dreaded. An earthquake is often the forerunner of an eruption, and the first warning of its approach. This has been generally the case with the principal volcanoes of the world, whose history is recorded. Earthquakes are often preceded by long droughts; but the earthquake does not immediately happen on the cessation of the drought, or the fall of rain. Electrical phenomena are not uncommon in the air, before the approach of an earthquake. The aurora borealis is frequent and brilliant, and bright meteors are often seen darting from one region of the heavens to another, or from the atmosphere to the earth. Before the shock of an earthquake, the waters of the ocean appear to be unusually agitated, without the effect of wind, or any other perceptible cause. Fountains and springs are also greatly disturbed, and become muddy. The air, at the time of the shock of an earthquake, has been often observed to be remarkably calm and serene, but it becomes afterwards dark and cloudy.

The noise which accompanies the shock of an earthquake, has been compared to that of a number of carriages driving with great rapidity along the pavement of a street; to that of the rushing of wind, and the explosions of artillery. The duration of the shock of an earthquake seldom exceeds a minute, and perhaps few continue even so long; but the shocks are sometimes repeated in rapid succession; and from the effect on the senses, and the dread and alarm thus excited, their duration is supposed to be much longer than it really is.

Earthquakes produce various effects on the surface of the earth, sometimes instantaneously heaving it up in a perpendicular direction, and sometimes communicating a kind of undulating or rolling motion from side to side. The shock sometimes commences with the perpendicular motion, and terminates with the other. Great openings, or fissures, are made in the earth, from which vast quantities of water, and sometimes smoke and flame, are ejected; and even where no chasm or fissure is produced, flame and smoke are often seen exuding from the surface. The effects of an earthquake on the ocean, are not less powerful than those on the land. The sea swells up to a great height; the waters seem to be entirely separated; and from the place of separation currents of air, smoke, and flame, are discharged. Similar effects are produced on lakes, ponds, and rivers. Places covered with water are converted into dry land, and dry land becomes an extensive lake, by the shock of an earthquake.

The effects of earthquakes are often very extensive, proceeding in different directions from the principal scene of desolation to very distant regions; but the most terrible earthquake that has yet visited the earth, has not been felt over its whole surface. The existence of an earthquake, it has been observed, is much more extensively indicated by water than by land; for where its effects have been imperceptible on dry land, the agitation produced in the waters of the ocean, of lakes and rivers, has been often communicated to a great distance. But the phenomena accompanying an earthquake will be better understood, by briefly detailing the history of particular earthquakes, in the account of which it will be found that most of the appearances and effects now enumerated were observed.

The earthquake which happened in Calabria in 1638, took place soon after violent eruptions of the volcanoes in that vicinity. Five years before, there had been an eruption of Mount Vesuvius, and two years only had elapsed from the time that a similar event had befallen Ætna; and indeed the latter mountain, at the very time of the earthquake, threw out a great body of smoke, which seemed to cover the whole island, and entirely conceal the shores from view. Immediately before the shock, the air over the sea was calm and serene, and the surface of the water was perfectly smooth. Without any visible cause, it began to be slightly agitated, in the same manner as the surface of the water in a heavy shower of rain. To this succeeded a dreadful noise, like the rattling of chariots, which increasing in frequency and intensity, was followed by a terrible shock, by which the earth was heaved up, or rolled in the form of waves. When the noise commenced, previous to the violence of the shock, a strong and offensive smell of sulphureous vapours arose. By this earthquake, many castles, villages, and towns, with all their inhabitants, were swallowed up. Among others, the city of Euphemia entirely disappeared. For some time after the dreadful catastrophe, a thick black cloud seemed to rest on the place, while the sky all around was clear and serene. When the cloud passed away, nothing remained on the spot where the city formerly stood, but a dismal and putrid lake.

The earthquake which visited Sicily in 1693, not only shook the whole island, but extended to Naples and Malta. The city of Catania was destroyed by this earthquake. Previous to the shock, a black cloud was seen hovering over it, and the sea appeared in violent agitation. The shocks then succeeded like the discharge of artillery, and the motion of the earth became so violent, that even those who lay on the ground were tossed from side to side, as on a rolling billow; almost every building in the countries which it visited, was thrown down; 54 cities and towns, beside many villages, were either greatly injured, or totally destroyed. Among these was the city of Catania, of which, after the thick cloud that remained after the earthquake, was dissipated, no remains could be seen; and of nearly 19,000 inhabitants, 18,000 at least perished by this dreadful calamity.

The earthquake which happened in Jamaica in 1692, also affords us an example of almost the whole of the phenomena already enumerated. On the 7th of June in that year, the town of Port Royal, then the capital of the island, was in two minutes totally destroyed by an earthquake. A hollow rattling noise preceded the shock, after which the streets were heaved up like waves of the ocean, and then instantly thrown down into deep pits. The wells discharged their waters, the sea burst its bounds, and the fissures produced in the earth were so great, that one of the streets seemed twice as broad as formerly. Many of these openings were seen at once, and in some of them the houses, inhabitants, and every thing that was near, were swallowed up. Some persons were carried down in one of these chasms, and what must appear extraordinary and almost incredible, were thrown up alive from another. From some of the fissures an immense body of water was projected to a great height into the air; the most offensive smells now succeeded, and nothing was heard but the distant noise of falling mountains; and the sky, which before the shock was still and serene, exhibited a dull red colour.

The effects of this earthquake were severely felt through the whole island; the wells in almost every part of it were either greatly agitated, or threw out their water with much violence. The current of the rivers was either interrupted, or ceased to flow for many hours, and some formed to themselves new channels. It was observed that the shock was most severely felt in the immediate vicinity of the mountains. Can it be supposed that this arose from the greater pressure and greater resistance, or was it because the force which produced these terrible effects, operated with greater intensity near them? During the period of two months after the earthquake which destroyed the town, repeated shocks were felt, which were so frequent, that two or three sometimes happened in the course of an hour. They were still accompanied with a rattling noise resembling thunder, or the rushing of a current of air in rapid motion. These shocks were also attended with what are denominated brimstone blasts, which are probably sulphureous vapours issuing from the earth. The atmosphere, indeed, for some time, was loaded with noisome vapours, for a general sickness succeeded, which in a short period carried off not fewer than 3000 persons.

But the earthquake which happened at Lisbon in the year 1755, far exceeded all others whose history is recorded, in the extent of its effects. Several shocks of earthquakes were felt in 1750, and the four succeeding years were remarkable for excessive drought. Springs which formerly yielded abundance of water, were totally dried up, and the prevailing winds were from the north and north-east. During this period also slight tremors of the earth were frequent. In 1755, the seasons were unusually wet, and the summers consequently proved uncommonly cold; but for 40 days before the earthquake, the sky became more clear and serene. On the last day of October, the face of the sun was greatly obscured, and a general gloom overspread the atmosphere. In the morning of the 1st of November, a thick fog arose, but it was soon dissipated by the heat of the sun. The heat of the weather was equal to that of June or July in Britain; not a breath of wind was stirring, the sea was perfectly calm and smooth. At 35 minutes after 9 in the morning, without any previous warning, except the rattling noise which resembled that of distant thunder, the earthquake came on with short quick vibrations, which shook the city to its foundations. By the effects of this shock, many houses instantly fell. A pause, which was just perceptible, then succeeded, and the motion changed. The houses were tossed from side to side, like the jolting motion of a waggon driven rapidly over rugged stones. By this second shock great part of the city was thrown down, and great numbers of the inhabitants were buried in the ruins. The whole duration of the earthquake did not exceed six minutes. The bed of the river was in many places raised to the very surface of the water; ships were driven from their moorings, and were tossed about with such violence, that the persons on board did not for some time know whether they were afloat or a-ground. A large pier with many hundreds of people upon it, sunk to an unknown depth, and not one of the dead bodies was ever found. The bar of the river was at one time seen dry from side to side, but suddenly the sea rolled in like a mountain, and in one part of the river the water rose instantaneously to the prodigious height of 50 feet. Another shock happened about noon, and the walls of some remaining houses were seen to open from top to bottom, near a foot wide, and were afterwards instantly closed, so that scarcely any mark of the injury could be perceived.

But the most singular circumstance in the history of this earthquake, is the prodigious extent to which its effects reached. At Colares, a place 20 miles from Lisbon, and 2 miles from the sea, the air was uncommonly warm on the day preceding the earthquake. At 4 in the afternoon a fog arose, which was an unusual occurrence at that season; it proceeded from the sea, and covered the valleys. The wind soon after shifted; the fog was again carried to the sea, and collecting over its surface, became thick and dark; and as the fog was dissipated, the sea was thrown into violent agitation, with great noise. At the dawn of day, on the 1st of November, the face of the sky was fair and clear; but about 9 o'clock the sun was overclouded, and became dim. About half an hour after, the rattling noise was heard, and increased to such a degree, that it resembled the noise occasioned by the discharge of the largest artillery. The shock of an earthquake was then felt, and was quickly succeeded by a second and a third. In these shocks it was observed that the walls of buildings moved from east to west; flames having the appearance of burning charcoal, and accompanied with thick black smoke, were seen issuing from some of the mountains. The smoke from one mountain was attended with noise, which increased with the quantity of smoke; but when the place from which the smoke arose was afterwards examined, no signs of fire could be seen. At Oporto, near the mouth of the Douro, the earthquake came on at 40 minutes past 9. The sky was quite serene, when the hollow rattling noise which preceded it was heard. In the space of a minute or two the river rose and fell five or six feet, and continued the same motion for four hours, during which time the bed of the river in some places seemed to open, and to discharge great quantities of air. St Ubes, a seaport town 20 miles south of Lisbon, was entirely swallowed up by the repeated shocks of this earthquake. Even large masses of rock were detached from a promontory, which terminates a chain of mountains of hard stone at the extremity of the town.

Almost every part of Spain experienced the effects of the same earthquake. In the bay of Cadiz it was not felt till a little before 10 o'clock. About 10 minutes after 11, a huge wave, not less than 60 feet high, was seen at the distance of 8 miles approaching the shore, and bursting upon the city. The water returned with the same violence with which it approached, and places which were deep at low water were left quite dry. The earthquake began at Gibraltar a little after 10 o'clock, with a tremulous motion of the earth, which continued for about half a minute. This was succeeded by a violent shock; the tremulous motion then returned, continued for five or six seconds, and was followed by a second shock, but less violent than the first. Many people were seized with sickness and giddiness, and fell down; the sea had also an extraordinary flux and reflux. The shock was felt at Madrid nearly about the same time as at Gibraltar, and the same sickness and giddiness prevailed. Many other places in Spain experienced similar effects.

The effects of this earthquake were not less severely felt in Africa than in Europe. About 10 in the morning, great part of the city of Algiers was thrown down. At Fez, and Mequinez, many houses were also destroyed, and many of the inhabitants were buried in the ruins. Many persons lost their lives at Morocco by the falling of houses; and, eight leagues from the city, the earth opened and swallowed up a village and all its inhabitants, to the number of 8000 or 10,000, with all their cattle. The earth soon after closed, and they were seen no more. Sallee and Tangiers also suffered greatly by an inundation of the sea; and when the waters retired, a great quantity of fish was left behind. The effects of the earthquake were also felt in other places along the African shore of the Mediterranean.

At 38 minutes past 9, the town of Funchal in Maderia experienced the first shock of this earthquake, and near 12 o'clock the sea suddenly rose with a great swell, and overflowed the shore. In the island of Antigua in the West Indies, the sea rose to a greater height than had been before known, and afterwards the water, which was six feet deep, was not more than two inches. About two in the afternoon, the sea ebbed and flowed unusually at Barbadoes, overflowed the wharfs, rushed into the streets, and this flux and reflux continued during the whole of the day.

Distinct shocks were felt in various parts of France, particularly at Bayonne, Bourdeaux, and Lyons. These shocks, in some places, were accompanied with subterraneous noises; the waters were greatly agitated, and many of the springs disappeared and continued dry for some time. At one place, a torrent of water, mixed with red sand, issued from an opening in the earth. The sea round Corsica was thrown into great agitation; many of the rivers of the island overflowed their banks. The earthquake was sensibly felt at Milan in Italy, and Turin experienced a smart shock. The waters and rivers of Germany were also greatly agitated; the lakes ebbed and flowed; noises were heard; and from some of the waters that were agitated, the most offensive smells were emitted. Some of the rivers of Switzerland became all at once muddy, without any previous fall of rain; a lake rose suddenly to the height of two feet above its usual level, and continued for a few hours at that height; and the waters of other lakes were also thrown into great commotion.

The waters in Holland were also greatly affected by this earthquake. The Rhine was so agitated, that large vessels parted from their cables, and smaller ones were thrown ashore. This happened in the afternoon; but at Amsterdam, about 11 in the forenoon, the waters of the canals were thrown into great agitation, and between 10 and 11, similar effects were observed in some of the canals at Leyden. Sweden and Norway also experienced the effects of this earthquake, not only in the commotion of the waters in rivers and lakes, but also in shocks of the earth, which in several of the provinces of Sweden were quite perceptible. Several smart shocks were felt at Fahlun, a town in the province of Dalecarlia.

The agitation of the waters was very perceptible in many places of England on the day of this earthquake. At Eton bridge in Kent, during a dead calm, a pond of an acre in extent was seen to open in the middle, while the water dashed over a perpendicular bank of two feet high. This motion was accompanied with a great noise. Between 10 and 11 o'clock in the forenoon, while a horse was drinking from a pond at Cobham in Surry, the waters retired from his mouth, and left the bottom of the pond dry. It then returned with great violence, and when it retired, its progress was southward. Similar effects were observed in Suffolk; and in Berkshire a tremulous motion of the earth was felt, accompanied by a commotion of the waters. At half after 10 of the same day, a sudden rushing noise, which seemed to proceed from a pond, was perceived near Durham; the water rose and fell four or five times in a minute for the space of six or seven minutes. No small degree of alarm was excited in Derbyshire by this earthquake; a sudden and terrible noise was heard, accompanied by a swell of water proceeding from the south; about 11 o'clock a shock was felt in the Peak, by which pieces of plaster were broken off from the sides of a room. The shock, as described by some miners who were at work, was so violent as to make the rocks grind upon one another. The water in a moat round a castle in Oxfordshire, exhibited a very unusual appearance about 10 o'clock in the morning of the same day. A thick fog prevailed; the air was quite calm, and the surface of the water quite smooth. At one corner of the moat, the flux and reflux of the water continued for some time quite regular and uniform; but at another corner, not more than 25 yards distant, no motion could be perceived. At three quarters after six in the evening of the same day, and about the time of two hours ebb of the tide, a great body of water rushed up in Glamorganshire, accompanied with great noise, and in such quantity, that it floated two vessels of 200 tons burden each. It must appear somewhat singular, that the effects of the earthquake should be felt at this place so much later than the time that its effects were observed in other parts of the island.

It is not less singular that the effects of this earthquake were felt in Scotland nearly about the time that it happened at Lisbon; for, about half an hour after nine in the morning, the waters of Loch Lomond were greatly agitated, and about the same time the waters of Loch Ness exhibited the same phenomenon. In both places the commotion continued till 11 o'clock.

The effects of the earthquake were not observed till between two and three o'clock in the afternoon, at Kinsale in Ireland. At that time it was perfectly calm, the tide was nearly full, and a great body of water burst with such violence into the harbour, that it drove two vessels from their moorings. The current of the water rushed rapidly along one side of the harbour, and ran down with the same force along the other. The agitation of the water extended several miles up the river, and was most perceptible in shallow places. In the evening the water rose again, but with less violence, and continued to ebb and flow till three in the morning. The waters, too, during this commotion, became thick and muddy, and emitted at the same time a very offensive smell. The agitation was accompanied with a hollow noise.

The effects of this earthquake were also severely felt at sea. Some vessels at a great distance from the principal scene of destruction, received so violent a shock, that it was supposed they had struck the ground. In one place of the Atlantic ocean, the craggy points of rocks appeared throwing up water of various colours, and seemingly resembling fire; at the same time a black cloud was seen to arise heavily in the atmosphere. In another part of the ocean, where it was supposed, from the violence of the shock, that the ship had struck a rock, on heaving the lead a great depth of water was found. The line was of a yellow colour, and gave out the smell of sulphur.

Very remarkable effects were produced on springs by this earthquake. The waters of some springs were observed to be greatly diminished, the day before the earthquake. This was the case with a fountain at Colares. On the morning of the 1st of November it became thick and muddy, but afterwards recovered its usual quantity and limpidity. In some places where there was formerly no water, springs appeared and became perennial; all the fountains at Tangier were dried up during the whole of the day of the earthquake; a hot mineral spring near a village in Bohemia became first thick and muddy, then ceased to flow for about a minute, and at last burst out with great violence. It became afterwards limpid, and flowed as formerly, but yielded a larger quantity of water of a higher temperature.

Britain has scarcely ever experienced any severe effects from the shock of earthquakes; but it has not entirely escaped from the alarms occasioned by these convulsions of nature. An earthquake visited London in March 1749, and was felt in a circuit of 30 miles diameter. The shocks of earthquakes were also felt in England in the following year. From the year 1789, for a period of more than 10 years, Comrie, and the places in its vicinity in Perthshire, have been frequently visited with shocks of earthquakes of various degrees of violence. One, which took place on the 5th of November 1789, excited very considerable alarm. It happened a few minutes before six o'clock in the evening. The noise which accompanied it, is described by some as resembling that of heavy loaded waggons, dragged with great velocity along a hard road or pavement. To others it appeared that some enormous weight had fallen from the roof of the house, and rolled with impetuosity along the floors of the rooms above. The waters of a lake in the neighbourhood, it is supposed, were thrown into commotion, for the wild fowl then upon it were heard to scream and flutter violently. The domestic animals were also greatly alarmed, and contributed not a little, by howling and screaming, to increase the terrors of the inhabitants. The general sensation which was experienced, was that of the slates and stones tumbling from the houses; in consequence of which, from the impression that the roofs were falling in, many persons ran out in great trepidation. The centre of these earthquakes was at the village of Comrie, and the concussion seems to have been limited to a space extending from east to west about 22 miles in length, by little more than 5 in breadth. The direction of the noise and of the concussion appears to have been nearly in the same line from north-west to south-east; but according to others, they sometimes proceeded in that direction, and sometimes from north-east to south-west.

Many speculations have been indulged by philosophers, to account for these terrible convulsions, which spread ruin and desolation in some of the fairest portions of the earth. According to some of the ancient philosophers, there are subterraneous clouds in the internal cavities of the earth, which, bursting into lightning, shake and demolish the vaults which contain them. Others supposed that the cause of earthquakes was the falling in of immense arched roofs, which confined the subterraneous fires; some ascribed these phenomena to the vapour of water, greatly rarefied by means of internal fires; and others accounted for their effects, by the explosion of certain inflammable substances which are exhaled from the internal cavities of the earth. Some modern philosophers suppose also the existence of such cavities, some of which contain water, and others are filled with vapours of different inflammable substances; and these combustible materials being kindled by some subterraneous spark, or actual flame proceeding through narrow fissures from without, or by the heat evolved during the chemical changes of different substances, produce the concussions of earthquakes on the surface of the earth. According to the hypothesis of Dr Woodward, water is continually raised in the state of vapour, by means of subterraneous heat, from the abyss which he supposes occupies the centre of the earth, to furnish rain and dew. When obstructions take place in this process, a swelling and commotion are occasioned; and this force being exerted against the incumbent strata, produce the agitation and concussion of earthquakes. M. Amontons supposes, that beyond the depth of about $\frac{1}{74}$th of the semidiameter of the earth, there is an immense spherical space, which is only filled with air; and as this air, from the state of its condensation, is only about $\frac{1}{4}$th lighter than mercury, equal degrees of heat increase its elastic force so much more than on the surface of the earth, that if the temperature of boiling water be applied, it will be more than sufficient to convulse and break up the superincumbent strata.

Such were the hypotheses which were employed to account for the phenomena of earthquakes, previous to the middle of the 18th century, when the knowledge of electricity began to be cultivated and improved. To the operations of this principle the phenomena of earthquakes were first ascribed by Dr Stukeley, who was then greatly occupied with electrical experiments. The same opinion was afterwards adopted, with various modifications, by Beccaria and Dr Priestley. Attempts have been made by others more modern, to account for the tremendous effects of earthquakes, by the agency of the vapour of water, or steam. But perhaps enough has been said on a subject which is yet involved in great obscurity. It is by no means improbable, however, that the phenomena of earthquakes may depend on the operation of more than one, or perhaps of all the causes to which their effects have been ascribed.

SECT. II.

OF VOLCANOES.

VOLCANOES exist in all climates of the world. Hecla in Iceland, and a volcano in Terra del Fuego, which terminates the southern continent of America, are situated nearly at the extremities of the globe. The number of volcanoes is nearly 200. The European volcanoes are, Vesuvius in

Italy, Ætna in Sicily, those of the Lipari islands on the coast of Italy, of which that of Stromboli is remarkable for having thrown out flames, without the ejection of other matters, for more than 2000 years; and Hecla in Iceland. There is one volcano in Mount Taurus in Asia, five in Kamtschatka, one in the island of Ceylon, ten in the islands of Japan, four in Sumatra, and some others in different parts of the Asiatic continent or islands. In the different groups of African islands, as the Azores, the Canary, and Cape de Verd islands, there are also several volcanoes. There are no fewer than 50 in the extensive continent of South America. Volcanoes have been long known in some of the islands of the West Indies, and some have also been discovered in the islands of the Pacific ocean.

The situation of the greater number of volcanoes is in the immediate vicinity of the sea. Volcanoes always occupy the tops of mountains. No volcano has yet been discovered in plains. The volcanoes at the bottom of the ocean seem to be an exception to this general remark; but these are also in the peaks of mountains, which have been raised up from the bottom of the ocean.

Among the first symptoms of the approaching eruption of a volcano, is an increase or commencement of the smoke in fair weather. The smoke, which is at first a whitish column, changes in the middle to black smoke. Explosions usually accompany those appearances. The black smoke is then followed by a reddish coloured flame; showers of stones with ashes are ejected, some of which rise to great heights in the air. These phenomena daily increase in frequency and violence, and are also usually preceded or accompanied by earthquakes and hollow noises. The increase of the smoke, flame, stones, and ashes, is continued, when at last the stones are thrown out red hot.

The smoke has been observed to be sometimes in a highly electrified state; flashes of lightning are seen darting from the smoke and ashes, sometimes attended with thunder; but it is supposed that the thunder and lightning are less intense than atmospheric electricity. These appearances continue for a longer or shorter time, as for four or five months, according to the nature of the eruption. After this the lava begins to flow, which is a current of melted matter, thrown out from the crater at the top of the mountain; or, when the mountain is high, as in the case of Ætna, it bursts out at the side, making a new passage for itself. The eruption continues to flow, sometimes for a few days, and sometimes for the space of several weeks.

It is a curious circumstance in the history of volcanoes, that when eruptions have begun, they follow each other in rapid succession; at other times they cease to flow for a great length of time. In the year 1447 Ætna ceased to throw out any flame till the year 1536, when a terrible eruption happened, accompanied with the usual phenomena. This awful conflagration raged with great violence for many weeks, and the torrents of flame and fused matter which flowed out, laid towns, villages, and vineyards, to a great extent, in ruins. For a century after this period, the eruptions of Ætna returned regularly at the end of 25 and 30 years. From the year 1686 to 1755, the same year in which the earthquake at Lisbon took place, Ætna remained for more than 50 years in a state of profound repose.

The first remarkable eruption of Vesuvius which is accurately known, happened in the 79th year of the Christian era. By this eruption the cities of Herculaneum and Pompeii were destroyed. This, however, was not the first eruption of that mountain, for it appears that the streets of these cities are paved with lava. Volcanoes become sometimes quite extinct, and are afterwards rekindled. Some of the Roman writers speak of Vesuvius only as having been a volcano. From that period it continued to burn for 1000 years, and became extinct again for a period of nearly 400 years, from some time after the beginning of the 12th century to the beginning of the 16th. Woods were growing on the sides of the crater, and even the crater itself had pools of water collected in its centre. Vesuvius has now been burning for three centuries past, and particularly during the 18th century.

So far as the history of submarine volcanoes is known, excepting in situation, they resemble the volcanoes on land. They also exist on the top of mountains, and eject immense masses of burning matter, with ashes and pumice, and torrents of lava. Submarine volcanoes have been observed at Santorin, one of the Greek islands, the Azores, and Iceland. In the year 1638, near the island of St Michael, one of the Azores, or Western Islands, in the Atlantic ocean, an island about six miles round arose, after an agitation of several weeks, in a part of the sea which was formerly known to be 120 feet deep; and in the course of a few weeks it was again swallowed up. The same volcano was in great agitation for some weeks in the year 1691, and a great quantity of flames, ashes, and pumice, was thrown out. Similar eruptions took place in 1720 and 1757.

The substances which are ejected from volcanoes are ashes, sand, pouzzolana, vitreous matters, tufa, pumice, and lavas, more or less consolidated. The ashes, sand, and pouzzolana of volcanoes, are in a loose state of aggregation. The pouzzolana is a well known substance, which is employed as a cement for building under water, and is peculiarly calculated for this purpose, in consequence of the oxides of iron and manganese which enter into its composition. Volcanic glass exists either in globules or large masses, and sometimes even forms entire currents like lava. It is rarely white and transparent, but most frequently opaque and variously coloured, exhibiting all the characters of a true enamel. Some of the vitreous matters ejected from volcanoes are of a compact texture, and others are so porous and light as to swim on water. In the cavities are sometimes found capillary filaments perfectly vitrified. Some remarkable vitreous filaments, of a yellowish colour, quite flexible, and from two to three feet in length, were ejected from the volcano in the isle of Bourbon in the year 1791. They were so light as to be carried about by the winds, and some fell on trees at the distance of ten leagues. Volcanic tufa is supposed to be formed from the ashes being mixed with water, thus forming a substance which is thrown out in the form of paste. It is supposed that Herculaneum was covered with a torrent of this volcanic matter. Pumice-stone is a light substance, of a fibrous texture, silky lustre, and whitish colour. It is not found in the neighbourhood of all volcanoes, but some volcanic eruptions seem to have been entirely composed of that matter. Such was the eruption which buried the city of Pompeii. It must be observed, however, that pumice-stone is not unfrequently met with in places where no volcano ever existed; and it seems not improbable, that some of the pumice-stone described by naturalists as being a volcanic production, because it is found in the neighbourhood of volcanoes, should be arranged among natural rocks. Such, for instance, are the currents of pumice-stone observed by Dolomieu in the island of Lipari.

Lava is another volcanic production, which is thrown out in a state of fusion, either from the crater itself, or from fissures or openings in the side of the mountain. The quantity of lava thrown out from a volcano, the velocity of its progress, and the distance to which it is carried, vary greatly, according to the violence of the eruption. Sometimes it runs slowly, and sometimes with such rapidity, as to pass over the space of a league in the course of an hour. Some currents of lava are described as exending 8 or 10 leagues in length, and a league in breadth.

Lava is generally of a porous nature, and often so light as to swim on water. Sometimes, however, substances which are described as lava, are so consolidated as to be susceptible of a considerable polish; but I think there is strong reason to suspect, that many natural rocks, that is, rocks which have never been subjected to the action of volcanic fires, are classed by naturalists among volcanic productions. The rocks thus considered as lava, seem to be precisely the same with the whinstone or basaltic rocks of this country. It is true, indeed, many of the French naturalists, among whom M. Faujas de St Fond is the most distinguished, regard all rocks of this description as the production of extinct volcanoes. That, however, is a controverted point, which involves a very different discussion; but it may be asserted that no modern volcano has ever thrown out lava which, by cooling slowly or suddenly in the open atmosphere, or under the waters of the ocean, has assumed the regular prismatic form of the basalt of this country. The proof derived from the similarity of analysis of basalt and lava, is equally favourable to the conclusion, that the natural rock of basalt in which the volcano exists, has been fused by heat, and converted into lava, and that the lava and basalt have the same origin. To those who are attached to speculative discussions of this nature, this point will afford a curious subject of investigation.

Lava sometimes contains imbedded in its substance entire and very perfect crystals of leucite, which, it is supposed, have been thrown out among the lava, unchanged by the volcanic fire. This circumstance has given rise to another discussion connected with volcanoes, and relative to the intensity of the heat, which, according to some, is not very great, as it has been incapable of producing any change on the leucite mentioned above, the crystals of which have frequently all their faces and angles well defined, and strongly marked.

Among the substances ejected from volcanoes, water, sometimes cold, and sometimes hot, has been frequently thrown out. Eruptions of water have happened both from Vesuvius and Ætna, and at one time Vesuvius threw out a quantity of salt water. Sulphur, sal ammoniac, and arsenic, have been also enumerated among volcanic productions; but it would appear that these substances are slowly sublimed, and deposited in the cavities and fissures, when the volcano may be considered rather in a state of repose.

Volcanoes of a different kind, called *mud volcanoes*, from ejecting a great quantity of mud, have been described. Many of the phenomena of those volcanoes are similar to those which are accompanied by fiery eruptions. There is a volcano of this kind in the island of Sicily, situated in a conical hill, truncated at the top, and about 150 feet high. Similar phenomena with those already described, precede the eruptions of this volcano, after which there is ejected a prodigious quantity of mud mixed with stones, some of which is carried to the height of 200 or 300 feet. A volcano of the same kind was discovered by Pallas in the peninsula of the Taurida, which forms a part of the Russian empire. A very copious eruption of this volcano took place in 1794.

Some of the volcanoes of South America come also under the same description as those of Cotopaxi and some others in the Andes of Quito, which occasionally discharge enormous quantities of argillaceous mud. But the most extraordinary circumstance connected with these volcanoes is, that fish are sometimes ejected along with the other matters. The fish are thrown out, sometimes from the crater at the top of the mountain, and sometimes by lateral vents; but always from places which are 2500 or 2600 fathoms above the level of the sea. It is even said that some of the fish were found still living, after being thrown out. To this species of fish Humboldt has given the name of *pimelodus cyclopum;* and as there are few of them found in the rivers in the vicinity above ground, he conjectures that they exist in great subterranean lakes, which have a communication with the cavities of the volcano *.

In investigating the causes of volcanic eruptions, various conjectures and opinions have been held by philosophers. By some they have been ascribed to the action of the waters of the ocean bursting in upon an immense quantity of fused or burning matter. Others derive their origin from the decomposition of different substances, by which a great quantity of heat and inflammable matters is produced, while others trace their causes to the direct action of central fires. But so many strong objections may be made to each of these opinions, some of

* Phil. Mag. vol. xxiv. p. 333.

which are quite obvious, that we may still consider the causes of volcanoes involved in great obscurity, and conclude with Humboldt, that "notwithstanding all the researches that have been recently made on volcanoes, there is nothing but the study of volcanic productions that has made any progress. As to the nature of the combustibles which nourish those subterranean fires, and the mode of action of those fires themselves, I believe that all persons who have visited the borders of craters, and who have lived a long time in the vicinity of volcanoes, will sincerely allow with me, that we are still very far from being able to give an explication which, without being contrary to the principles of chemistry and of physics, could account for the great phenomena which volcanic explosions present *."

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* Phil. Mag. vol. xxiv. p. 338.

CHAP. VI.

OF THEORIES OF THE EARTH.

A DETAILED account of the speculations of philosophers concerning the original formation of the earth, or of the successive changes to which it has been subjected, might afford some amusement to the reader, and might not perhaps be altogether devoid of instruction, as it would exhibit, in a striking light, the rashness, folly, and presumption of the human mind, in overleaping the bounds of sober investigation and calm inquiry. It is a more difficult task to examine nature herself, to collect and to arrange facts, and to estimate the conclusions which may be fairly deduced from them; than to suppose, with Buffon, that the earth was a spark separated from the body of the sun by the collision of a comet; or with Burnet, that the antediluvian state of the earth gave place to the present, in consequence of the heat of the sun producing fissures and openings, by which the waters of a central abyss burst forth; and part of the surface of the globe having fallen in, now shows the ruins of a former world. But as the prescribed limits of this work are nearly occupied with matter which, I trust, will be deemed by many far more useful, I shall content myself with giving a mere outline of the two theories which have divided the opinions of some of the geologists of this country, and indeed have excited a good deal of the warmth, and some degree of the asperity, of controversial discussion. The theories alluded to are those of Hutton and Werner; with regard to which, and to all other theories of the earth that have been hitherto proposed, I cannot avoid expressing a doubt, whether that advanced state of physical science, which it has been justly remarked by one theoretical writer on this subject, is necessary for such investigations, be yet arrived; and indeed the unsettled state of the facts on which any rational theory can be founded, is a pretty strong proof that this period is not yet completed.

Theory of Hutton.—The object of Dr Hutton was not, as we are informed by his biographer *, to explain the first origin of things. His specu-

* Mr Playfair. Edin. Trans. vol. v.

lations were limited to those changes to which terrestrial bodies have been subjected since the establishment of the present order.

1. The first general fact in support of this theory is, that the greater part of the bodies of which the exterior crust of the globe is composed, exhibits the marks of being formed out of the materials of mineral or organized bodies of a more ancient date; and although the spoils of an older world are not found in every piece of rock, yet they are every where visible in the present system, and are so generally diffused as to leave no doubt that the strata which now compose the present continents, are formed out of more ancient strata.

2. The second general fact on which this theory rests is, that the present rocks, excepting such as are unstratified, have been all deposited at the bottom of the sea; and having been collected in the form of loose materials, they have been consolidated by some powerful and general agent. This agent is supposed to be subterranean heat, and it is said that the author of the theory has removed the objections to this assumption, by introducing the principle of compression, which must have prevailed in that region where the consolidation of mineral bodies was effected; for it is alleged, that under the weight of a superincumbent ocean, the utmost intensity of the heat is unable to volatilize those substances which at the surface, and merely under the pressure of the at-

mosphere, are entirely consumed. It is supposed also that the same degree of pressure, by forcing those substances to remain united, which at the surface are easily separated, might effect the fusion of some bodies which are only calcined in our fires.

3. The third general argument adduced in support of this theory is, that the stratified rocks, instead of being in a horizontal position, as it is supposed they were originally, are now observed to be placed in all degrees of elevation, and some even perpendicular to the horizon; and besides, many of the strata which were once at the bottom of the sea, are now raised up several thousand feet above its surface. From this circumstance, and from the bendings, the fractures, and separation of the strata, it is inferred that they have been elevated by means of some expansive force acting under them; a force which has burst in pieces the solid pavement on which the ocean rests, and has raised up rocks from the bottom of the sea into mountains 15,000 feet above its surface. Thus, according to this theory, the rocks were first consolidated by heat, and then elevated by the same agent acting with an expansive power.

4. The fourth argument in support of this theory, is derived from the disturbances which abound in the mineral kingdom, and particularly those great breaches among rocks which are filled

with materials different from the rock on either side. Such are metallic veins, as well as the veins or dykes of whinstone, porphyry, or granite. These are supposed to be of posterior formation to the strata which they intersect, and in general carry with them the marks of violence with which they have been introduced, and of the disturbance which they have occasioned in the rocks already formed. According to the view of Dr Hutton, the materials of all these veins have been in a state of fusion by means of subterraneous heat, and in this state they have been injected among the fissures and openings of rocks already formed. All the masses of whinstone, porphyry, and granite, which are interposed among strata, or raised up in pyramids through the midst of the strata, are supposed to have been in a state of fusion; and thus, in the fusion and injection of the unstratified rocks, consists the last of the great operations of subterraneous heat on mineral bodies.

5. The next part of this theory relates to the changes to which mineral bodies are subjected after they are raised into the atmosphere; and according to it they are all going to decay; the hardest, as well as the softest bodies, are wasting, and undergoing a separation of their parts; and being resolved into their elements, are carried down by the rivers, and deposited at the bottom of the sea.

The following general reflections on this theory I shall give in the words of Dr Hutton's biographer: "On comparing," says he, "the first and the last of the propositions just enumerated, it is impossible not to perceive that they are two steps of the same progression, and that mineral substances are alternately dissolved and renewed. These vicissitudes may have been often repeated, and there are not wanting remains among mineral bodies that lead us back to continents from which the present are the third in succession. Here then we have a series of great natural revolutions in the condition of the earth's surface, of which, as the author of this theory has remarked, we neither see the beginning nor the end; and this circumstance accords well with what is known concerning other parts of the economy of the world. In the continuation of the different species of animals and vegetables that inhabit the earth, we discern neither a beginning nor an end; and in the planetary motions, where geometry has carried the eye so far both into the future and the past, we discover no mark either of the commencement or termination of the present order. It is unreasonable indeed to suppose, that such marks should any where exist. The Author of Nature has not given laws to the universe which, like the constitutions of men, carry in themselves the elements of their own destruction; he has not permitted in his works any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. He may put an end, as he no doubt gave a beginning, to the present system, at some determinate period of time; but we may rest assured that this great catastrophe will not be brought about by the laws now existing, and that it is not indicated by any thing which we perceive."

Theory of Werner.—This theory may be considered as the reverse of the preceding; for, according to it, all mineral substances have been in a state of solution or suspension in water. According to this theory, all rocks are divided into three great classes, primary, transition, and secondary; and it is supposed that the characters of these different classes of rocks warrant the conclusion, that they have been formed at different periods.

1. The primitive class of rocks constitutes not only the highest parts of the surface of the earth, but also supports all other rocks. This class of rocks is characterised by being in a more perfect state of crystallization than the incumbent rocks, and it exhibits no remains of animals or of vegetables. The inferences deduced from these circumstances are, that the rocks possessed of the above characters were the first formed; that they are to be considered as chemical depositions; and that they were produced before the existence of organized beings.

According to the language employed in this theory, the different classes of rocks are composed of a number of different layers, which are distinguished by the name of *formations*, and these layers or formations are supposed to have succeeded each other in a certain determinate order; for, from the observations made by those who have adopted the theory, they are found in the same relative position in every quarter of the globe. They are also, from the same circumstance, denominated *universal formations*. The water which held in solution the materials of which the primitive rocks consist, it is supposed, surrounded the whole earth to a greater height than the highest mountains of the globe. From this fluid, successive layers or depositions of various degrees of thickness were produced; and as these formations took place by a slow and gradual deposition, they are now characterised by a kind of confused crystallization.

2. After the formation of the primitive class of rocks, the waters holding in solution the other materials of which the following classes of rocks are composed, diminished in height; the primitive rocks were then above the surface of the water. Part of those rocks is supposed to have suffered decay from the action of the weather, and masses were also broken off by the agitation of the waters; these being mixed with the solution, were deposited along with the next class of rocks, which ex-

hibits the characters of a deposition partly mechanical and partly crystalline. Hence it is inferred, that this class of rocks being incumbent on the primitive rocks, being less elevated, and of a more earthy and less crystallized structure, was formed in the circumstances now mentioned. No remains of vegetables or of land animals, it is said, have been found in this class of rocks; a few indications only of marine animals have been observed: and hence it is inferred, that the consolidation of this class of rocks must have taken place before the existence of vegetables or land animals. The formation of this class of rocks is also in this theory denominated *universal*, and they have received the name of transition, because they were formed when the earth was passing from an uninhabited to an inhabited state.

3. As the rocks thus formed were more and more exposed by the diminution and subsidence of the waters, they were subjected to still greater disintegration. The materials thus separated were mixed in greater abundance with that part of the solution remaining; and hence mechanical deposition became more prevalent, and chemical deposition more sparing. The characters possessed by the next class of rocks, the secondary, are supposed to warrant these conclusions. These rocks are disposed in horizontal strata, and they exhibit more of an earthy, and less of a crystalline appearance, than the rocks which compose the pre-

ceding classes. This class of rocks is particularly distinguished by a great abundance of the remains of organic beings. The formation of the secondary class of rocks is also supposed to have been universal.

The strata which accompany coal are deposited in patches, and are therefore supposed to constitute only a partial formation; and hence this class of rocks is distinguished by the name of the *independent coal formation*. The strata of which this class of rocks is composed, are incumbent on the transition rocks.

There is another class of rocks which, according to the theory, was produced among the last of the series. This has been denominated the *floetz trap formation*. It consists of basalt, wacken, and greenstone, and is incumbent on all other rocks. The rocks belonging to this formation now exist in detached masses among the secondary strata, or covering some of the transition rocks, because it has been subjected to a greater degree of waste and decay than other rocks.

The diversity and inequality of surface which appear on the earth, are accounted for, in this theory, from the different degrees of durability of different rocks, in resisting the waste and decay which are continually going on. Primitive rocks possessing, from their peculiarity of structure, a greater degree of hardness and cohesion, appear to be the most durable. The present arrangement and position of the various strata on the surface of the earth, are also supposed to depend on inequalities of the nucleus on which they were originally deposited.

In all theories of the earth, the formation of mineral veins always constitutes a prominent feature. According to this theory, fissures were produced after the subsidence of the waters, by the drying and shrinking of the newly formed strata; and in these fissures the various mineral substances with which they are now filled, were deposited from solution in water. And as those veins afford the finest examples of the perfect crystallization of mineral bodies, this circumstance is supposed to arise from the waters holding these substances in solution, being less liable to agitation than during the deposition of the horizontal strata.

Those who wish for a more detailed account of the above theories, may consult Hutton's Theory of the Earth; Playfair's Illustrations of the Huttonian Theory; Thomson's Chemistry, vol. iv.; Murray's Chemistry, vol. iv.; Comparative View of the Neptunian and Huttonian Theories, and Journal de Physique, tome lv.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. is a transverse vertical section of the strata, containing the rock salt at Wieliczka in Poland; *a* represents the vegetable soil, 2 fathoms thick; *b* is a sandy clay, 5 fathoms; *c* is a very fine sand like tripoli, which contains carbonate of lime, as it effervesces with acids. The thickness of this stratum is 3½ fathoms. *d* is a stratum 9 fathoms thick, composed of marl with sand and loose stones; *e*, a stratum of sandstone about 6 feet thick; *f* is a stratum consisting of marl mixed with salt in small particles and cubes. It is in this marl, at the depth of 20 fathoms, that the rock salt is found in the form of large irregular rocks or masses, which are represented by the shaded parts at the bottom of the figure.

Fig. 2. is a horizontal section of a whin-dyke, in which a slip or separation has taken place; *a a*,

the dyke; *b c*, *d e*, the slip, which is exactly equal to the thickness of the dyke, as the opposite sides of the dyke *d c* are brought into the same line.

Fig. 3. shows the effect of whin-dykes traversing coal strata; *a b* are two whin-dykes which traverse the stratum of coal *c c c*, and the accompanying strata, which are represented by the different shading in the figure. The first dyke *a* throws the coal from *d* to *e*, and the second dyke again depresses the coal from *e* to *d*. The corresponding strata between the two dykes, and on their opposite sides, are seen at *f f f* and at *g g g*.

Fig. 4. a section of a mining field, showing in what manner the veins are distributed; *a a*, the surface; *b b b b*, veins descending from the surface through the horizontal strata; *c c c c*, the upper or hanging side of the vein, or, as it is called simply, the hanger; *d d d*, the ledger or lying side, or ledger; *e e e*, the vein interrupted and shifted; *f f f*, the vein dividing into strings or branches.

Fig. 5. a section of a tin vein; *a a*, the surface; *b b b b*, the vein of tin thrown off its course at the points *c c c c*, by the dykes *d d d*. The extent of the dislocation is in proportion to the magnitude of the dyke. These dykes are called by the Cornish miners *Gossans* and *Flookans*.

Plate II.

Fig. 6. is a section of the singular coal strata at Quarrelton in Renfrewshire; *a a a* is the surface,

which in many places exhibits the whinstone rock *c c c*; *b* is a small patch of gravel and sand; *d d d* is the stratum of sandstone, and the strata immediately above the coal; *e e e*, the coal itself; *f g* and *h i* are two slips or dislocations of the strata, the first 30, and the other 50 feet; *k k* are pits or shafts sunk to the coal.

Fig. 7. is another section of the same coal field; *a a a* is the surface; *b* is the patch of gravel; *c c* is the whinstone covering the coal strata; *d d d*, the sandstone lying above the coal; *e*, the coal stratum, where it seems to be overlapped, producing a thickness of not less than 60 or 70 feet of coal. Something of the same kind appears at *f* and *g*, but the strata have not come into contact; they are separated by a body of sandstone at *m*. In sinking the shaft *k*, the object was to find the coal at *m*; but in passing through the sandstone, a very unexpected but fortunate discovery of a large mass of coal was made at *n*. *h i* is the same hitch or slip of 30 feet, as *f g* in the former section, and *l* is the same shaft as *k* on the left side of the section of fig. 6.

Fig. 8. is a section of a very remarkable distribution of the coal strata of Anzin, near Valenciennes; A B include alternate and horizontal strata of chalk, marl, and clay, which are incumbent on the coal strata; *a b c d e* are the strata of coal, which are sometimes nearly in a vertical, and sometimes nearly in a horizontal

position, in consequence of being folded upwards or downwards, as may be seen at *f f f f*. The same letters, it is to be observed, represent the same strata as they are bent upwards or downwards, along with the accompanying strata which follow the same course, as may be seen by casting the eye on the figure.

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